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ANNALS of SURGERY

VOL. LXX SEPTEMBER, 1919 No. 3

REPORT OF 82 CASES OF KNEE-JOINT WAR INJURIES FROM EVACUATION HOSPITAL 1, A.E.F., WITH REMARKS ON THE WILLEMS' TREATMENT BY IMMEDIATE CLOSURE AND SUBSEQUENT MOBILIZATION, AND THE MANAGEMENT OF THE SUBSEQUENT INFECTION BY DRAINAGE AND MOBILIZATIONS*

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NOTHING more startling has appeared in the outcome of this war's surgical experience than the surprisingly good, final, functional results obtained by Willems in his treatment of knee-joint injuries by immediate, active mobilizations. Willems gives the following statistics in regard to the final outcome in 100 of his consecutive knee cases, 18 of which were accompanied by a purulent synovitis of a virulent type, chiefly streptococcus. In the 100 cases there were no deaths and no amputations. There was one resection and two stiff joints. These are very striking results. In comparison those obtained in the A. E. F. by the use of the old-time immobilization method, even though somewhat modified by the direction of earlier motions, suffer markedly, particularly in the septic cases. The causes of these poorer results are three:

First.—Incomplete knowledge of the Willems treatment, or fear of possible experimentation. It should be the duty of our Medical Schools to teach this method so that it will supplant the old immobilization dogma, which should be discarded, except in well-indicated cases where fragments would be dislocated by the motions.

Second.—The insufficient number of nurses in the hospitals of the A. E. F. to carry out systematically the motions. A day nurse and a night nurse *au courant* with the method are indispensable in each hospital.

Third.—Too early evacuation of the patients. A strict rule should be made that no post-operative joint injury should be evacuated within ten days of the operation, for two reasons:

* Read before the American Surgical Association, June 16, 1919.

A. The early jolting of transportation predisposes to infection.

B. The journey requires a splint which immobilizes the joint, leading to advanced peri-articular œdema and to the deposition of intra-articular fibrin, both of which make more difficult subsequent mobilizing motions. Early evacuations were the rule in the American Army.

Those of us who have seen Doctor Willems demonstrate his method and witnessed his results, and those of us who have followed out his procedures are all converts to his plan of treatment, however skeptical we were beforehand. The object of this paper is to express the hope that the Willems mobilizing method will be applied to civil injuries to joints that better functional results may follow both in septic as well as in aseptic joint lesions.

Fractures.—In 32 patients of the 82 there was no fracture present. In 8 there were simple fractures, while in the remaining 40 there were all combinations of comminuted fractures, the patellæ being fractured in 18, the femora in 29, the tibiæ in 12 and the fibula in 1.

Clean Cases.—Of 73 cases operated upon in Evacuation Hospital 1, for knee-joint injuries, of whom we have final reports by the Surgeon General's office as to infection, 57 remained clean, or 78 per cent. This is an excellent showing. Twenty-one surgeons reported on these cases, so that the results speak well for the careful technic of the operators so far as asepsis is concerned. In 70 of 76 known cases the synovial membrane was completely closed while 6 were drained into the joint.

Motions in the Clean Cases.—In general one could say that Willems' treatment was not well carried out. Generally a splint was not used, except in cases where a fracture made it imperative, but the lack of night nurses made active motions at night impossible and in the daytime the patient was left to make the motions by himself. There was no general system, even in the daytime, for forcing the patients to make active motions regularly. Even with this abortive plan, all the operators say that early motion gave excellent results, function having returned well in a short time. Then the too early evacuations stiffened the joints sometimes irretrievably. An illustration of the after-treatment, written by the operator who did 15 of these cases, is as follows: "These 15 cases were splinted from 2 to 4 days postoperative, at which time motion was begun, at first passive, then active; patient out of bed and walking at end of two weeks if contra-indicating fracture not present." This is not Willems' treatment of knee-joint injuries as advocated by him. He does not use a splint even in the beginning and starts active motion (never passive) at once.

We have information from the Surgeon General's office as to the final results, so far as motions are concerned, in 36 of the cases which remained clean. Of these 36 patients, 9 had perfect function at discharge, or to duty, that is 25 per cent. (These are in the Table, Nos. 16, 22, 38, 40, 49, 68, 76, 81, 82.) There was ankylosis in 3 clean cases, or 8 per cent. In 24 there was some motion in varying degrees, or 67 per cent. These 24 patients were

not well classified as to the degree of motion, but here are the records as they appear in the reports of the Surgeon General's office:

	Patients
Slight flexion	1
Knee "somewhat stiff"	1
Slight limitation of flexion	2
Limitation of flexion	10
25 degrees of flexion	1
Flexion not possible beyond a right angle	4
50 degrees of flexion	2
Flexion to 90 degrees	1
Flexion to 140 degrees	2
Total	24

29 patients were sent back to duty, 25 without classification; two with C2, one with CC2, and one with Class A.

Infection of the Knee and its Results.—We have accurate reports in 73 cases as to infection, obtained from the Surgeon General's office on completion of the case. Of these 73 cases, 16 became subsequently infected, or 22 per cent., that is, one-fifth of the cases. Thus

Case	Time between injury and operation	Result
11	6½	Ankylosis.
12	4½	Amputation.
13	9½	Death from Streptococci septicæmia.
15	81	No final report on function obtainable from S. G. O.
18	16	Death from sepsis.
20	16	Ankylosis.
34	11	No final report on functions obtainable. Remaining a patient in hospital March 31, 1919.
42	15	Amputation.
44	4½	Ankylosis.
54	Unknown	Amputation.
66	7	Resection.
69	Unknown	No final report on functions, remaining a patient in hospital, March 31, 1919.
70	Unknown	Died from pyæmia.
71	Unknown	Died from septicæmia.
79	11	Ankylosis.
80	11	Flexion to 90 degrees two months post operation, with dislocation of knee (reduced).

From this it appears that the average duration was ten and four-fifths hours excluding the eighty-one-hour case. Many of these patients had complicated comminuted fractures, but it is noteworthy to remark that five of these septic cases had no fracture of the bones of the joint. To sum these results up, we find 4 with ankylosis, 1 with resection, 3 with amputations, 4 died as the immediate result of the subsequent infection, 1 with flexion to 90 degrees two months after operation, 3 no report of functions obtainable.

These are the melancholy results of infection treated more or less

along the old lines of immobilization. Of 13 patients whose final result we know only one had any motion whatsoever in his knee, 3 have had amputations, 1 a resection, 4 were ankylosed, while 4 died. These were all treated by a modified old plan, *i.e.*, with somewhat earlier motions. We should adopt the Willems treatment in these cases in order to obtain better results, surely they could be much improved. Drainage with Willems' immediate immobilization afterwards is much better than by any other method as there are no stagnant pools of pus left, since, if motions are frequent and vigorous enough, the pus is expelled as it forms. The mobilizations are intended as much for affording adequate drainage as for preserving the joint movements, and adequate drainage is what is needed to confine the infection to the synovial membrane and to prevent its spread to the cartilage and bone.

The opinion of surgeons in the Base Hospitals is that an infected knee is a very serious thing; first, for life; second, for limb; and third, for function especially. For the most part, because of the early evacuation of these septic cases, when they have arrived at the Base Hospitals, motion is already gone, due to the necessary immobilization for transportation, and once that is lost, it has been found practically impossible to regain it. Consequently there are three chief indications in these septic cases: First, adequate incisions for efficient drainage; second, active motions to be begun immediately after the operations and to watch unceasingly that they never be stopped even for a day; third, there should be no evacuation to another hospital within ten days of the operation. At the Base Hospitals the *non-mobile* infected joints have been very difficult to handle owing to the poor drainage, many of them having extensions of their infections up into the thigh or down the leg, running septic temperatures and finally requiring amputations to save life. Cases that have come back to the Base Hospitals able and willing to move their joints (the exceptions) have done well, owing to the good drainage brought about by the motions. *These knee-joint cases should never be transported from an Evacuation Hospital to a Base Hospital within ten days of the injury.* This cannot be too strongly emphasized. Doctor Willems is thoroughly imbued with the belief that many would be saved joint and limb by the treatment which he advocates. That better functional results and a larger percentage of cures are obtained by his method than by the old immobilization procedure there can be no doubt.[1]

Duration of the Injuries Before Operation.—From the appended figures can be gained an idea of the efficiency of the Transport Department of our army. Thus, of 61 cases in which the time between the receipt of the injury and the operation is known, 25 cases, or 42 per cent., were received within eight hours, 37 cases, or 60 per cent., within 12 hours, and 47 cases, or 77 per cent., were operated upon within 16 hours of the receipt of the injury. There were only 9 cases received after 20 hours. This speaks volumes for the rapidity with which the wounded were brought to the hospital, consider-

[1] United States Naval Medical Bulletin, Bainbridge, 1919, January, 1919, p. 61.

ing the difficulties to be overcome. The time elapsed between the receipt of the injury and the operation is known in 61 cases, thus: Within two hours, 1 case; in third hour, 1 case; in fourth hour, 4 cases; in fifth hour, 4 cases; in sixth hour, 9 cases; in seventh hour, 6 cases; in eighth hour, 1 case. Thus within eight hours there were 26 cases out of 61, or 42 per cent., of the whole.

From the tenth to the twelfth hour inclusive, 11 cases, a total of 37 cases out of 61, or 60 per cent. of the whole.

From the thirteenth to the sixteenth hour 10 cases, a total of 47 cases out of 61, or 77 per cent. of the whole.

From the seventeenth to the twentieth hour, inclusive, 5 cases, a total of 52 cases out of 61, or 85 per cent.

Over 20 hours, 9 cases, thus: 23 hours, 3 cases; 26 hours, 1 case; 32 hours, 1 case; 40 hours, 2 cases; 55 hours, 1 case; 82 hours, 1 case.

Closure.—There is definite information in 76 patients as to whether the joint capsule was closed or not at the primary operation. In 70 it was so closed, while the joint was left open in 6 of the 70 with closed capsule; the external tissues leading down to the closed capsule were left open in 28, or 40 per cent.

Ligation of Vessels.—Ligation of popliteal vessels was required in 3 cases, thus, of the vein (77), death from shock; of both vessels (39), followed by gangrene and amputation; and of the artery (41), followed by good function after thirty-four days. From our observations it has been almost universally true that in war injuries ligation of both popliteal artery and vein leads to gangrene of the leg.

Deaths.—Of the entire 82 patients, 9 died, or 10 per cent. The time before the operations and the cause of the deaths are as follows:

Deaths		Time between injury and operation
13	Streptococcus septicæmia	9½ hours
18	Pyæmia	23 hours
19	Numerous wounds	13 hours
21	Secondary hemorrhage from thigh wound, 15 days after operation	5 hours
31	Gas gangrene of thigh	20 hours
37	Numerous wounds. Shock	6 hours
70	Pyæmia	Duration of injury not given
71	Septicæmia	Duration of injury not given
77	Shock	6 hours

Nature of the Missiles.—In all of the cases this information is given. From these figures is elicited the fact that the prepondering number of wounds was caused by shell fragments. Such wounds are admittedly the most poisonous because the shell before explosion usually touches the ground, carrying with it the most virulent infection. These wounds are also of the severest character because of the irregularity of the fragments in size and contour. Thus: of the 82 cases, 54, or 66 per cent., were caused by shell fragments; 26, or 32 per cent., were the result of bullets (machine

guns, rifles, revolvers), while 2, or 2 per cent., were not caused by missiles but one by an aeroplane propellor and the other by a fall.

General Principles of Willems' Treatment.—Preliminary Röntgen-ray examination of the joint with the object of determining the degree of fracture, if any, also the marking out on the surface of the position of the foreign body beneath. At the operation careful débridement of all the damaged tissues surrounding the wound, external to the opening in the synovial membrane, and the removal of all the hemorrhages in the fascial planes about the wound. Changing of the instruments, or re-sterilization before entering the joint. Removal of the contused edges of the synovial wound with its enlargement up and down sufficiently to do the necessary subsequent work. The joint should be kept open just as short a time as possible in order that the synovial membrane may dry as little as possible, since a dry synovial membrane seems to predispose to ankylosis. Removal of the foreign body, all clothing and loose detached bone fragments. Smoothing off of all rough bone edges. If the foreign body is buried in the bone, it is chiselled away, following the tract to its end and removing all the devitalized bone surrounding the tract. If possible, all the procedures should be performed without the gloved hands being introduced into the joint, or without touching any contacting part of the instruments to be introduced. At this stage, one will determine whether there is sufficient undamaged articular cartilage left to make possible the hope of subsequent restoration of function by immediate, post-operative, mobilizing movements. The joint is then thoroughly washed out with any unirritating bland solution, such as Dakin's, or normal salt solution, followed, finally, by a flushing with pure ether, and then the capsular opening edges are completely closed with a plain continuous catgut suture either through and through, or, as some prefer, so passed that no suture appears inside the joint. Unless the effusion into the joint is frank pus, as in neglected cases, the synovial membrane is completely closed, disregarding the length of time that the injury has existed prior to the operation. The tissues external to the closed capsular wound need not be closed, however, and had better not be, if the injury has existed over twelve hours. The external open wound may be loosely packed with gauze, wet in Dakin's solution, or Carrel's tubes may be placed in position in the wound for subsequent treatments with Dakin's solution. The important point to be emphasized is that the entire opening in the synovial membrane *must* be completely closed.

A bandage is so loosely passed about the dressing as not to impede subsequent movements.

At the time the joint is open, a culture is taken of its contents to subsequently determine the presence or absence of hæmolytic streptococci which, when found, requires speedy drainage of the joint. No splint to be applied, and this is all important.

After Treatment.—Just as soon as the patient is out of the anæsthetic, he is made to *actively* (never passively) move the articulation in bed. Pas-

sive motions are painful and set up an inflammatory reaction, and later on an extra-articular abscess may be caused to rupture into the joint. The patient's hands grasp the sides of the thigh, which is lifted from the bed by muscular contractions, his heel remaining resting on the mattress. At first there is excessive fear of trying these motions, but as the pain is felt to be very slight, courage is soon established. The sooner motions are begun after the operation the less is the pain, because the peri-articular structures do not have time to become infiltrated with exudate. The nurse sees that this is done every two hours, night and day, to the greatest extent possible, short of actual pain. To the faithfulness, consequently, of the nurse in following these instructions will be due the subsequent restoration of function. There is astonishingly little pain when active motions are started immediately after the operation, providing no bony fragments are displaced, in which case movements are not indicated. Patients say that if painful sensations appear during repose, the best means of making them disappear is to repeat the movements.

There will frequently occur, after the operation, a hemorrhagic effusion into the joint, upon the appearance of which motions become impossible, depending upon the amount of fluid present. This should be at once aspirated, to be followed immediately by the resumption, as before, of the active motions, which become possible as soon as the joint is emptied of fluid. It may be necessary to aspirate the joint a number of times, a bacteriological examination being made each time to determine the presence or absence of infection. (See case No. 16 in Table.)

The patient on the second or third day is made to get out of bed and take a few steps on the joint without crutches. It is astonishing how little pain is experienced on walking, if active motions have been begun immediately after the operation, and how soon almost perfect function is restored.

Management of Septic Knee-joints from War Injuries.—As soon as frank pus is evident, either by signs of inflammation or bacteriological examination, thorough drainage must be at once established by vertical external and internal incisions. The joint is washed out thoroughly with Dakin's solution at the time of the operation. Tubes had preferably better not be used at first but may be later, if drainage is found to be insufficient. When they are used, the internal ends should project just inside the synovial membrane and no further. The after-treatment is conducted exactly as in the case of non-infected joints by active (not passive) motions carried out to the point of pain. These are begun immediately after the anæsthetic has worn off and are repeated every two hours thereafter, day and night. Even a day's delay will prejudice the final functional result. Walking is important because the muscular contractions compress the joint and cause a marked increase in the expulsion of pus. The patient is made to walk the next day after the operation without crutches. It is surprising how much pus will exude from the incisions after each walk. It is very important that sufficient drainage openings be made to allow for an adequate escape of the pus.

These openings should be sutured just as soon as the discharge becomes serous. If the active motions are performed often enough and vigorously enough, these secretions are expelled through the drainage openings as they are formed. Drainage seems to be more thoroughly accomplished by this method than by any other, thus limiting the infection to the synovial membrane and tending to prevent its spread to the cartilage and bones.

In civil injuries the results of operations with débridement, joint closure and immediate subsequent mobilization should be much better than in war injuries, because ordinarily the patient is operated upon more quickly, the infection is not so virulent, there is no transfer to another hospital, and, finally, the after-nursing should be more effectually done.

The following are the divisions of joint lesions by projectiles as made by Willems.[1]

1. *Simple traumatic hydrarthrosis* or hæmoarthrosis without penetration of the joint cavity. This requires immediate aspiration with no subsequent splinting. We do not ordinarily aspirate these joints early enough or often enough. Active motions of flexion and extension with walking on the knee at once should be immediately instituted. This is a radical departure from the old established immobilization, and it is quickly very successful. That the abolition of movements is due simply to the presence of the fluid is shown by the fact that movements are possible immediately following the emptying of the joint.

2. *Joint Wounds Without Injury to the Bone.*—The treatment for this is outlined above in the previous part of this paper. Sometimes while active motions are going along well, there will be a sudden functional impotence. Examination will show an effusion into the joint. This must be aspirated at once, a culture being taken of this. Upon removal of the fluid active movements and walking should be made as before the aspiration. The aspirations may have to be repeated several times.

3. *Articular Wounds with Small Bony Lesions.*—Among these are the perforations of the epiphysis, erosions of the cartilage, the raising up of bone fragments from the surface, and losses of deeper fragments but which are superficially small in extent. All these lesions have this in common that they leave intact the greatest part of the articular surface, and there is no great fragment detached or detachable, consequently there can be no displacement by motions. The post-operative treatment is exactly like that of articular wounds without bone injury.

4. *Articular Wounds with Bony Lesions of Middling Severity.*—By these we mean those in which an important fragment of an epiphysis is detached. These are the oblique transcondylar fractures. The danger in them is the dislocation of the articular line. Active, immediate mobilization should be begun at once, but in the knee walking should be interdicted for about three weeks in order that sufficient consolidation should take place to prevent dis-

[1] Bull. et Mém. de la Soc. de Paris, October 9, November 13, 1917, and January 15, 1919.

placement of the fragment. In fractures of the patella, Willems encircles the fragments with a buried silkworm-gut suture and treats them afterwards with active motions and immediate gentle walking. His results are excellent.

5. *Articular Wounds with Large Bony Fragments.*—When the fracture is one of the varieties of the T-fracture, the limb must be submitted to continuous extension, mobilizations being delayed for consolidation in order to preserve the articular line.

In conclusion the authors desire to note Doctor Willems [1] in the following summary of the rules which are essential to be followed in carrying out his method:

"Active mobilizations should be begun without any delay and should be carried as far as the patient is in a condition to do it. It should be done without interruption, even to the point of fatigue. This mobilization is not painful in the true sense of the word, it is only laborious and it is necessary to compel the patient to do it, to tease him if he is lacking in courage.

"It is never necessary to add passive movements to the active movements with the expectation of hastening the process.

"Patients treated by this method never present any serious alteration of their general condition, even during the early febrile period. They never look like those who have been severely infected. They do not fear movements as do those who are immobilized. Even in purulent arthritis it is striking to note that the joint has not the excessive sensibility which an infected joint presents when it is cared for by immobilization."

The authors thank most heartily the various operators of these patients for permission to include their cases in this report. Their names are purposely not mentioned in order that this report may be entirely impersonal, the desire being to ascertain the average results. Thanks are also given to Surgeon General Ireland of the United States Army, and to Colonel Gibbon, Director of the Surgical Service, for permission to publish this report.

CONCLUSIONS

1. No joint injury should be evacuated within ten days after the operation.
2. The joint should be completely closed at the operation.
3. No splint should be used except in those cases where fragments will be displaced.
4. The Willems after-treatment of immediate, continuous, active motions should be unceasingly kept up day and night both in the aseptic and septic cases.
5. In each hospital there should be a day and a night nurse who should be conversant with the method and whose only function it should be to carry out the active motions.

[1] ANNALS OF SURGERY, February, 1919, p. 221.

TREATMENT OF RECENT WOUNDS OF THE KNEE-JOINT*

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and

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We will confine our remarks to the immediate treatment of wounds of the knee-joint by projectiles, that is, bullets, fragments of shells, etc. The observations upon which the paper is based are mainly 34 cases operated upon by the writers at Evacuation Hospital No. 1, A. E. F.

One of the most important lessons which war surgery has taught is the amenability to surgical treatment of wounds of the large joints. The pessimistic views which were formerly held in regard to these lesions were due to an undervaluation of the resistance to contamination and infection which the synovial membrane of a joint offers; and a failure to comprehend the proper operative procedures. But during the last two years of the war it became evident that the features which are of importance in the treatment of battle casualties of other types, particularly early operation and complete excision of traumatized and contaminated tissue with removal of foreign bodies, are likewise indicated in the treatment of wounds of the large joints. But, whereas in other types of wounds it was often found advisable to leave the wound unsutured and to supplement the operative treatment by chemical sterilization before proceeding to a final closure, in the case of a joint primary closure of the synovial membrane is essential to success, and an unsutured joint with or without post-operative chemical sterilization has not in general proved satisfactory. Therefore, since the surgeon must rely upon the primary operation for the prevention of intra-articular infection, the principles of debridement as applied to wounds of the soft parts, bones and cartilage must be understood and practiced.

Indications for Operative Treatment of Recent Wounds of Joints.—All wounds of joints by projectiles, except certain perforating (through and through) wounds by bullets, should be operated upon.

Perforating bullet wounds are not operated upon by most surgeons if the wounds of entrance and exit are punctate and there is no evidence of displacement of fragments or hemorrhage. Punctate wounds are made by a bullet of high velocity with no explosive effect and no deflection during its course through the limb. In such cases the bullet cuts through clothing and tissues carrying few organisms into the wound and producing little destruction of soft tissues or comminution of bone. Experience has demonstrated that under these conditions infection usually does not occur even

* Read before the American Surgical Association, June 16, 1919.

when a fracture is present. Therefore these cases do not demand immediate operation. They should, however, be carefully watched and distention of the joint should be treated in the manner described in the after-care of operated cases.

A careful preliminary examination of the patient and his lesions is essential. The extent of involvement of the bone and the presence and position of retained foreign bodies should be established by the X-ray. Moreover, the time elapsed since the wound was received, the location of the wound, the extent of injury to the soft parts, complicating lesions of the main blood-vessels and large nerves, and the general condition of the patient are, as in other battle casualties, factors which must be weighed before a plan of action can be decided upon.

After careful consideration of the conditions enumerated the surgeon should proceed as far as possible in accordance with a definite plan. The choice between amputation and conservation of the limb usually should be made before the operation is begun; the choice between resection and joint preservation is made as the operation proceeds.

We will not dwell upon the indications for amputation as it is with the technic of conservative treatment that we are mainly concerned. We believe that the results of conservative treatment are sufficiently good to weigh in its favor in cases of doubt, and that more mistakes will be made by a persistently radical than by a persistently conservative policy. While the degree of mutilation of the soft parts and the extent of comminution of bone are of great importance in deciding for or against amputation, it is in cases complicated by wounds of the main vessels that the decision is most difficult and most urgent. In the cases which we observed where an open knee-joint was associated with a wound of the popliteal or femoral artery, amputation ultimately became necessary except in one instance. This exception was an open knee-joint without bone involvement complicated by a wound of the popliteal artery. Arthrotomy and ligation of the popliteal artery were followed by a good functional result.

Technic.—The principles of conservative treatment may be summarized as follows: Complete débridement of the tract of the projectile through the joint; absolute closure of the joint by suture; primary or delayed closure of the superficial parts according to the rules laid down for primary suture of the soft parts alone; finally, early active motion.

The incision or incisions must be placed so as to permit not only thorough débridement of the soft parts, but also free access to the foreign body and involved bone. Though no rule can be formulated, longitudinal incisions, especially lateral incisions, are to be preferred when practicable. However, the position of the wound or wounds is in general the determining factor. Occasionally the incision may be curved or even transverse, but division of the patellar tendon should rarely be made. The primary incision includes the wound of entrance and is often supplemented by a second incision. In a perforating wound the second incision includes the wound of exit; in a

penetrating wound it is placed in such position as to expose a retained foreign body which otherwise would be inaccessible.

It is sometimes necessary to supplement a longitudinal incision of the superficial tissues and capsule by a limited transverse incision of the capsule.

Through these incisions débridement of the soft parts proceeds as in operations elsewhere. The technic is practically the same as for wounds of the soft parts alone. The niceties of technic in respect to asepsis and adequate exposure must be fully observed, and traumatization of the synovial membrane should be reduced to a minimum.

We will consider first the simplest type of case: a type, however, which is relatively frequent, namely, small perforating and penetrating wounds with little or no bone involvement. In these the bullet or fragment of shell has either perforated the limb, traversing the joint in its course; or has penetrated the joint and lodged in it or in adjacent tissues. In some of these it is difficult to determine whether the joint has been penetrated. But, after the capsule has been exposed, the orifice into the joint must be demonstrated before the joint is opened. Great care should be exercised to avoid opening a joint that is uninvolved, and, similarly, not to neglect proper operative measures in a joint that is involved. The capsule and synovial membrane should be opened by a liberal incision with thorough elliptical débridement, conserving, however, all tissues that can be left safely. Foreign bodies must be removed, also loose fragments of bone. A wound of the bone or articular cartilage should be treated as outlined later. The joint is thoroughly irrigated with salt-solution and then distended several times with ether. The synovial membrane and capsule are closed with fine catgut. When feasible these two layers should be sutured independently. *Complete closure of the joint without drainage is the invariable rule.* The soft parts overlying the capsule may be closed or left open for subsequent suture according to the same rules as are followed in wounds of the soft parts alone. In wounds of limited extent operated upon early and retained for observation a primary closure may be practiced. Otherwise the soft parts should be left open. Delayed primary suture may then be made in many cases within a week. Primary suture increases the danger of joint infection by inward extension of a superficial infection. On the other hand, leaving the soft parts unsutured may delay the institution of early movements.

When, as is often the case, the tract involves an articular surface with destruction of bone and cartilage, the tract must be followed and cleansed as thoroughly as possible. That is, it is treated on the principle of removal of contaminated tissue. This should be done with gouge, chisel, curette or elevator, but with the sacrifice of as little bone as possible. The curette is less satisfactory but is often necessary. Obviously the débridement cannot be and should not be as thorough as that of the soft parts.

In some of our cases the injury to the articular surface has consisted in a limited and incomplete separation of a layer of cartilage with a thin layer of underlying bone. In such cases it is advisable to remove the partly

separated and poorly nourished layer of cartilage and to cleanse with chisel, gouge or curette the surface from which it has been detached.

Where a considerable area of condyle or articulating surface with a preponderance of bone is partially detached but retains good contact with the overlying soft parts, the fragment is left after the tract has been followed and the fractured surfaces have been cleansed as thoroughly as possible. If an attached fragment is to be removed this should be done if possible by the subperiosteal method of Lariche using his modification of the sharp Ollier elevator. By this method a reformation of the bone is more probable. Compound fractures of the *patella* should be treated by removal of completely separated fragments and preservation of large attached fragments which should be approximated if possible by suture. Complete removal of the patella should be avoided, since the functional result is poor.

In extensive involvement of the articular surfaces, an effort should be made to save the joint, provided the conservable articular surfaces and soft parts are sufficient to warrant a reasonable hope of securing a useful joint. In this connection it must be borne in mind that stability is essential in the knee.

When there is such loss of the articular surfaces as to preclude obtaining a useful joint, resection should be elected. As Lemaitre emphasizes, primary resection is to be preferred to a poor functional result with deformity. For instance, complete removal of a condyle will result in so much lateral mobility as to necessitate subsequent resection. When the bone lesion is so extensive as to necessitate resection through the narrow shaft above the condyles, amputation is in general preferable.

When there is such destruction of the soft parts that the edges of the capsule cannot be approximated; if an attempt is to be made to save the joint, the defect in the capsule should be completely closed with muscle or fascia. In cases where this was impossible, we have seen a partial closure made and the wound treated by the Carrel method, the aim being to close the joint subsequently by a plastic operation. However, we have not seen this method successfully carried out without infection. Much difficulty may be experienced when excision of a portion of the head of the tibia has been necessary. The defect is difficult to close. When the loss of articular surface is slight we found it possible to supplement the deficiency in the capsule by turning in a flap of fascia from an adjoining part and suturing it in place so as to complete the closure. If the loss of articular surface is considerable resection is usually necessary.

In all cases before the joint is closed complete hæmostasis should be obtained. The joint is then thoroughly washed with salt solution to remove blood, bone fragments and débris. This is followed by lavage with ether under sufficient pressure to distend the joint. Although this use of ether is empirical it appears to exert a beneficial influence. Closure of the joint is obligatory.

In compound fractures associated with a wound above or below the knee in which the joint is not directly involved, but with one or more lines of fracture extending into the joint, infection frequently develops. If hæmarthrosis is marked we believe that arthrotomy, irrigation and closure is in general indicated in addition to the operative treatment of the wound.

Post-operative Care.—It must be emphasized that the ultimate outcome of the case, namely the early reëstablishment of the function of the part, must be aimed at from the first. *Early active mobilization is the rule.* The patient should be encouraged and directed to move the joint as soon as the operator feels that this can be done without exciting hemorrhage or interfering with tissue repair. For instance, following a transverse wound with removal or suture of the patella, or after summary suture of an extensive wound involving the muscles of the thigh, a period of immobilization must be enforced. On the other hand, in the type of wound with little involvement of bone and soft parts a splint need not be applied; the patient should flex and extend the knee as soon as possible and he may be allowed to walk by the tenth day or sooner. Early use of the joint is essential for early restoration of function. *In the treatment of wounds associated with fracture,* mobilization of the joint is not indicated if it is likely to interfere with alignment or union or promote excessive callus formation.

Though we approve of the doctrine of Willems, we practiced early mobility rather than immediate mobility in the post-operative treatment of our clean closed joints.

Superficial infection may only require the removal of a few stitches; more extensive infection of the superficial tissues requires reopening of the entire wound to the capsule. The wound should be Carrelled and may be suturable subsequently.

If the joint becomes distended, and infection is suspected, it should be aspirated immediately and a culture made. We have seen turbid fluid containing diplococci aspirated from a distended joint on the third day after operation and uneventful recovery follow; we have also seen much turbid fluid evacuated from between the sutures in the capsule on the second and again on the fourth day by pressure on the subcrural bursa. In this case the joint was markedly distended until the fourth day. Possibly as a result of that distention, there was no limitation of motion by the soft parts at any time. This patient quickly regained complete function and was back at the front in six weeks.

If the patient's condition, the local examination, the character or culture of the aspirated fluid indicate pyogenic infection, lateral incisions should be made at once, or if the original incision is so placed as to allow satisfactory drainage it should be reopened and the treatment for suppurative arthritis begun.

Suppurative Arthritis of the Knee-joint.—Willems' method is here recommended. The important feature is to drain early. Lateral incisions well back are the best; occasionally an incision elsewhere may be employed.

No drains should be used. Splints are dispensed with or arranged for support without joint fixation. Free mobility every two hours should be enforced by *active* movements so as to evacuate the joint. Early non-virulent infections with little or no bone involvement usually do well. In severe or long-standing infections, especially with bone involvement, the treatment has not proved as satisfactory.

We have not included in this paper any reports or discussion of those long-standing and destructive infections of the knee-joint which demand resection or amputation. Our observations of wounds of the knee-joint has been to a large extent in an evacuation hospital under conditions favorable for long observation, and for estimation of the probable end results. Although serious complications may have developed in some of the cases included in our series after they passed from our care, we believe that by the methods of treatment which have been outlined serious complications can as a rule be avoided. For these methods we are indebted to the surgeons of Belgium and France.

Analysis of Cases.—In tabulating our cases, we have analyzed the pre-operative histories with reference to the time elapsing before operation, the type of missile, the nature of the wound, the presence or absence of fracture, and the pre-operative complications. The large proportion of wounds due to high explosives, as contrasted with those resulting from small arms, and the great majority of those penetrating and associated with a retained foreign body, was a characteristic feature of the prevailing trench warfare. The pistol wounds were of the accidental type, and were for the most part associated with severe fractures.

Total number of wounds of the knee-joint operated upon		34
Average time elapsing before operation (excluding one case of 3 days' duration in a French soldier)		11 hours
Shortest interval		3½ hours
Longest interval		26 hours
Type of missile	High explosive	25
	Pistol	5
	Rifle or machine gun	4
Penetrating wounds		25
High explosive		23
Pistol or rifle		2
Perforating wounds		9
High explosive		2
Pistol or rifle		7
Wounds with bone involvement		28
Femur		12
Femur and tibia		3
Femur and patella		6
Tibia		3
Patella		4

Wounds without bone involvement 6
Complications.—Multiple wounds 10
Wounds of main blood-vessels 3
Femoral artery 1
Popliteal artery 1
Popliteal artery and vein 1
Contusion of peroneal nerve 2
Shock or hemorrhage or both 4
Gas gangrene (pre-operative) 2

In all except two cases the joint was sutured primarily. In one case primary amputation was necessary and in another an attempt was made to save a badly shattered limb, in which the wound of the knee-joint was of secondary importance. This case came to amputation, but not for joint infection.

Primary amputation 1
Primary suture of joint 32
Primary closure of superficial wound 21
Delayed primary closure superficial wound 4
Secondary suture superficial wound 4
Evacuated before suture of superficial wound 2
Amputation for vascular gangrene before skin wound was sutured..... 1
Amputation for gangrene of foot in case in which joint and soft parts were not closed. Gangrene resulted from gaiter with traction for 2 days prior to admission in French soldier 1

Wound Healing.—The preservation of life, limb and function are mainly dependent on the avoidance of wound infection, and in the treatment of infected wounds of the type under consideration the success of the operation may be judged in part by the percentage of cases in which the surgeon is able to avoid or control this factor. The results obtained in our series are as follows:

Total number of infections during stay in hospital 8
Infections.—Of joint and soft parts after primary suture 3
Infection of soft parts alone, severe, requiring reopening, Carrel and secondary suture 1
Infection limited and superficial, requiring the removal of only one or two sutures, not interfering with primary wound healing 4
Evacuated within twenty-four hours (this case was amputated at the base, details are lacking) 1

While in three cases there occurred joint infection, in but one did this result in ankylosis. In the others the infection was controlled by prompt reopening and Carrel treatment for two days. In both of these the joint was sutured successfully after sterilization.

Secondary Amputations.—In two cases this was required before evacuation. In neither was it done for infection. In one it was for gangrene following an associated wound of the popliteal artery and vein, and in the

second for gangrene of the foot, the result of prolonged pressure by the anklet used in connection with the Thomas splint which had been in place for two days before admission. In another case evacuated 24 hours after operation the record shows the limb was amputated later at a Base.

End Results.—The average length of stay in the hospital was twenty-six days. Four patients at the end of several months were reported to be under treatment for a partial fibrous ankylosis with fair function. In these cases further improvement may reasonably be expected.

Deaths.—Total number	2
1. Multiple wounds, gas gangrene, retroperitoneal infection.	
2. Multiple wounds, shock, gas gangrene.	
Amputations primary	1
Amputations secondary	2
Good functional result apparently assured at time of evacuation or from subsequent information. (Little or no limitation of joint movement and a stable weight-bearing limb)	15
Fair result (partial limitation of motion after several months; good weight-bearing limb)	4
Poor result from standpoint of function (one complete ankylosis the result of infection; one secondary resection for weak joint)	2
Result as to function undetermined	7
One case evacuated within 24 hours, amputation at base	1

A review of the above results has confirmed us in the opinion that a conservative policy in dealing with wounds of the knee-joint caused by projectiles is justifiable and strongly indicated, whether it be viewed from the standpoint of mortality, preservation of limb or maintenance of function. It has shown us that infection can be avoided in the great majority of cases; that even when intra-articular infection develops function can sometimes be preserved, or if lost that amputation is not inevitable. Finally, that early active motion of the joint offers the best chance for an early and complete restoration of function.

CASE REPORTS

THE following are reports of such cases as present features of special interest:

CASE I.—Captain X. Wounded at 5 A.M., March 11, 1918, by a shell which exploded in the trench. Admitted about 7 P.M.; operating room at once, fourteen hours after injury. 1. Wound outer side of left knee 3 inches above joint; moderate hæmarthrosis. X-ray showed foreign body in exernal condyle.

Operation.—Three-inch longitudinal incision with excision of trajet which passed along and opened joint for 1¼ inches. Edges of opened synovial membrane excised. Trajet led into condyle. This traced inward led to firmly embedded éclat one inch deep in bone fracturing articular surface. Edges of orifice in bone removed with rongeur, tract thoroughly curetted after removing éclat 8 mm. diameter. Joint irrigated with saline and then ether. Synovial mem-

brane completely closed. Superficial tissues sutured. Skin closed without drainage.

Arm.—Two wounds middle of arm, (1) posterior; (2) external. X-ray showed two éclats, inner aspect of humerus above fracture; markedly comminuted fracture middle ⅓ humerus. Longitudinal incisions removing each wound; careful débridement including a number of small splinters scattered through the tissues. Musculospiral nerve dissected three inches showed no evidence of injury. Third longitudinal incision over foreign bodies. These reached through biceps and removed, and tracts excised to bone. Posterior wound presented lacerated, bloodless, gray muscle; this freely excised. Cultures and smears of arm wounds revealed few staphylococci.

Dressings.—Arm, Thomas, patient elevated with weights. Leg, Cabot, elevated with weights.

March 13th: Temperature, 99°; pulse, 80. Comfortable. Dressed forty-eight hours. Knee no effusion, clean. Arm clean, culture negative. Smears few cocci—1:5 fields.

March 14th: Seventy hours post-operative, delayed primary suture of arm (three wounds).

March 15th: Temperature, etc., normal. Comfortable.

March 17th: Temperature, etc., normal. Wounds dressed, clean. Swelling and ecchymosis of arm, no tenderness.

March 18th: Seventh day, began active motion knee 5 degrees.

Late result: Knee full function; arm was subsequently operated upon for musculospiral paralysis. June, 1919, function of musculospiral is returning; apparently will soon have perfect use of muscles supplied by it.

Case II (March 12, 1918).—Wounded by shell fragment penetrating knee. Operation four and one-half hours later. Transverse incision with débridement. Patella was in small fragments. Internal condyle in small fragments. Foreign body in popliteal space. Fragments of patella and condyle removed; foreign body removed through popliteal incision which was left open. Synovial membrane closed as fully as possible; soft parts closed completely.

March 14th: Dressed. Considerable bleeding has occurred from posterior wound. Wounds look clean.

March 20th: Movement of knee begun.

March 21st: Posterior wound (popliteal) sutured under anæsthesia. Movements tested, little lateral mobility and free flexion.

March 23rd: Put up with balanced weights for support during active motion. Flexion 15°. Temperature runs to 100°.

March 28th: Developed tonsillitis; temperature, 103°; continued for five days.

April 5th: Out of bed. To bear weight on leg daily and active movements. Hæmatoma developed in popliteal space opened and ℥iii

blood clot evacuated. On evacuation, May 9th, wounds healed, can flex 10° without pain, some fluid in joint.

The consideration of procedure at time of operation was as follows: Resection would mean great shortening; also a weak union due to peg-like narrow end of femur; also same dangers from infection as accompany conservative procedure. Subperiosteal resection was not feasible on account of length of such an operation and the marked comminution. Amputation seemed too radical primarily; better deferred until result observed. It is probable, however, that resection or amputation would have been best since the patient will probably have a flail-joint. It has been ascertained that resection of the knee-joint was performed August 21, 1918.

Case III (March 26, 1918).—Wounded by shell fragment striking right knee. Walked two kilos. Operation three and one-half hours after injury. Much effusion. Small wound over patella. Éclat 5 inches higher in muscles of thigh. Patella fractured at upper part. Evidently struck on upper end of patella while knee was flexed. Six-inch incision with débridement. Joint irrigated with saline and ether and closed. Tract through muscles could not be followed, therefore blindly excised and foreign body removed. Feared to close on account of possibility of anaërobes in muscles of thigh with questionable débridement. (Organisms, –1 : 5 fields; anaërobes and diplococci in tissue removed with éclat.)

March 27th (eighteen hours, dressed) : Two organisms to field; culture, no growth.

March 28th, 9.30 A.M. (forty hours post-operative) : Delayed primary suture. Fourth day considerable bleeding. Hæmatoma in soft parts and swelling of knee.

April 9th: Hæmatoma evacuated, wound sutured with rubber tissue drain.

April 17th: Primary union, active motion.

Evacuated May 9th. Went back to his organization about May 15th and was on duty during the fight near Soissons, taking long marches, etc., with no discomfort.

August 2d examined, no limp, flexion to right angle. Scar soft, movable, and no apparent adhesions.

April 2, 1919: Seen in New York, no discomfort, full use; 135° flexion.

Case IV.—Shell wound penetrating right knee, sustained April 9, 1918. Operation twenty-six hours later. Marked effusion, tenderness and pain. X-ray showed foreign body 1 cm. outer side middle of outer condyle 1 cm. above articular margin. Excision wound of entrance and tract by longitudinal incision 3 inches long inner side of knee-joint. Joint distended with rather thick blood containing fat droplets. Smears showed one coccus to 5 fields. Towards end of evacuation of blood, pus was noted; cul-de-sac already contained pus. Joint washed thoroughly with saline followed by ether. Longitudinal incision on outer side, joint opened and foreign body removed; débridement. Joint washed again. Synovial membrane closed on both

sides with interrupted catgut; capsule closed; silkworm gut at angles of both wounds, centres left open and Carrel gauze inserted. Cabot splint slightly flexed. No post-operative swelling, no fever, etc.

April 14th: –1 : 5 fields-culture-diplococci. Delayed primary suture on basis of smear and culture.

Primary union, motion good on evacuation, May 9th, one month.

Case V (April 10, 1918).—Shell fragment penetrating knee-joint. Entrance outer side joint almost in joint cleft. Operation eighteen and one-half hours later. Longitudinal incision, débridement. Joint distended with bloody fluid. Fragment passed through joint and was embedded in tissues below and anterior to joint. Foreign body removed. Smears showed Gram-positive cocci 4-field. (Culture subsequently reported diplococci and Gram-positive B.) Joint irrigated with saline followed by ether. Synovial membrane closed, capsule closed. Superficial parts closed with silkworm except small area in middle of wound. Eighteen hours, no swelling, no fever, wound looks clean. Thirty-six hours, considerable swelling of cul-de-sac; pressure evacuated about 2 ounces of mucoid-like fluid.

April 14th (fourth day): Pressure evacuated same fluid.

April 17th (seventh day): No fluid comes out on pressure; little on dressing; moves knee actively.

On evacuation, May 9th (one month), walking, full flexion.

Foreign body, deep in muscles of thigh. Débridement. Culture-diplococci. Thirty-six hours, delayed primary suture, success.

Foreign body in muscles of leg. Débridement. Dressed twelve hours, culture 1-2 fields diplococci. Thirty-six hours delayed primary suture, primary union, success. Large piece of wood in back, superficial. Excision and primary suture, success.

May 21st returned to his organization. Seen on June 26th, perfect condition, is on way back from front.

Case VI (April 11, 1918).—Shell fragment penetrating knee outer aspect. Foreign body retained. Operation nine hours after receipt of wound. Longitudinal incision outer side with débridement of tract, including orifice in capsule and synovial membrane. Longitudinal incision on inner side; foreign body removed and tract excised. Joint irrigated with saline followed by ether. Synovial membrane closed. Remainder of wound left open.

April 12th: Inner wound smear, 0. Culture Gram-neg. B. Outer wound smear, 0. Culture Gram-neg. B.

April 15th: Wounds of soft parts sutured with silkworm.

April 17th: Primary union, begin active motion few minutes daily.

April 22d: On evacuation good motion.

Case VII (April 17, 1918).—Shell fragment penetrating right knee. Wounded while kneeling. Entrance one inch above patella. Foreign body ½ cm., imbedded in articular surface of femur. Operation eighteen and one-half hours after wounding. Longitudinal incision 4 inches long in midline from patella upward. Tract excised. Joint distended with yellowish fluid (one organism to 3 fields), culture gave no growth. Knee was fully flexed and this brought area con-

taining éclat into view above patella. With chisel and gouge éclat and surrounding bone removed. Irrigation. Complete closure. Cabot splint.

April 23rd: Primary union. Flex actively and repeatedly. Never any pain or fever; 99° highest since operation. A little feeling of fullness in and around the knee, but no distention.

Almost full mobility on evacuation, May 9th. Walking without crutches.

Case VIII (April 20, 1918).—Penetrating shell wound of left knee, bone involvement. Operation seven hours after wounding. Entrance outer side of external condyle of femur. X-ray showed foreign body 2 cm. in diameter in external condyle of femur. Hæmarthrosis extreme.

Operation.—Longitudinal incision outer side, tract excised. Foreign body 2 by 2 cm. imbedded in outer condyle, removed. Edges of cavity removed with rongeur and cavity well curetted and washed with saline followed by ether. Joint similarly irrigated. Articular surface of condyle partially detached as a whole, somewhat mobile but left in place. Complete suture. Cabot splint. Forty-eight hours later dressed; looks well; little fluid; can flex knee without pain.

Sixth day: No splint; to move knee. Evacuated May 9th (eighteen days) with flexion about 45°.

December 22, 1918: Flexion, 100°. No atrophy.

March 11, 1919: Slight limitation of flexion.

Case IX (April 21, 1918).—Multiple shell wounds. Operation eleven and one-half hours after wounding. Knee, head, arm, feet, thighs, legs, etc. Many small wounds over both knees.

Penetrating of right knee. Hæmarthrosis. Two tracts traced and excised to capsule. Pressure on cul-de-sac evacuated much blood from joint through small opening which had escaped observation. Knee opened on inner side and edges of orifice in capsule excised; foreign body not found.

To X-ray room. Foreign body 4 by 3 mm. embedded in inner tuberosity of tibia only reached on extreme flexion of joint; removed; another foreign body extra-articular, left. Joint irrigated and sutured.

April 24th: Up to present no pain nor swelling in knee, seems to be doing well. Both knees free flexion and extension.

Other wounds débrided. Foot. Extensive laceration. Débridement, 12 foreign bodies removed.

April 24th: Looks well. Carrel to date. On evacuation clean granulating surfaces.

Left knee. April 23rd. Looks like top of pepper box with small fragments and tracts, two removed from in front of patella.

April 24th: Swelling of knee, not tense. Needle inserted outer side and 70 c.c. of bloody mucoid-like fluid aspirated. Six foreign bodies then removed from neighborhood; one into patella tendon with foul tract. Tract excised. Splint for knee. Culture of fluid aspirated Gram-positive non-spore bearing bacilli; few diplococci.

X-ray revealed 13 more foreign bodies scattered through the soft

tissues about the knee-joint. One minute fragment is probably buried in cartilage over external condyle of femur. No further complications.

Evacuated May 14th. Motion good in both knees.

Case X (June 10, 1918).—Right leg; compound fracture of tibia and fibula; penetrating wound of knee; compound fracture of internal condyle of femur, hæmarthrosis after receipt of wound. Small opening on inner aspect of knee-joint from which considerable blood and joint fluid drained. Operation five and one-half hours after wounding. Longitudinal incision. Excision of edges of wound and débridement. Foreign body removed. Joint irrigated with saline solution followed by ether. Wound closed; Thomas splint.

June 19th: Primary union.

July 25th: Seen at a base hospital, fracture united. Beginning to sively débrided.

Case XI (June 16, 1918).—Multiple wounds high explosive shell inner side right knee-joint, foreign body passing through inner condyle and imbedded in outer condyle. Operation twenty hours after receipt of wound. Débridement. Foreign body removed. Irrigation with saline and ether. Joint closed. Soft parts left open.

Right thigh; four lacerated wounds side by side across middle third. Femoral artery had been wounded; ligated; muscles extenmove knee. Should get good functional result.

Left thigh; wound deep and very dirty. Excision of tissues. Wound back of mastoid very dirty; débridement; foreign body removed. Right arm, perforating wound of lower third; débridement; not sutured.

Left foot badly lacerated wound, amputation.

Patient died twenty-four hours later from gas bacillus infection of right thigh.

Case XII (June 16, 1918).—Wounds multiple, from shell fragments. (1) Right knee; foreign body in internal condyle half way between anterior and posterior extremities of its articular surface. Entrance above and to outer side of patella. Operation fifteen hours after receipt of wound. Long incision. Débridement; foreign body removed. Bone cavity cleaned with rongeur and curette; irrigation saline and ether; joint closed, soft parts sutured.

(2) Foreign body imbedded in upper extremity of tibia below articular surface; tract débrided; foreign body removed; bone cavity curetted; irrigation; wound closed.

(3 and 4) Right leg; two foreign bodies; débridement; wound closed.

(5) Right ankle; entrance anteriorly; large foreign body penetrated ankle-joint and lodged in astragalus. Débridement; bone cavity curetted; irrigated; wound closed.

(6) Left elbow. Foreign body 3 by 2 by 1 cm., lodged against outer condyle of humerus and olecranon; synovial membrane pierced; some comminution of humerus and ulna. Débridement; foreign body removed; joint irrigated with ether and closed.

(7) Laceration of left foot, disarticulation at metatarso-tarsal articulation. Inner cuneiform removed. Carrel-Dakin treatment.

June 18th: Dressing in operating room with Savariaud; anæsthesia right knee looked well, though some swelling. Right ankle; considerable swelling and tenderness. Left elbow; some redness, swelling and tenderness. Left foot (stump); Carrel dressing. Early active movements of joints encouraged.

July 9th (twenty-three days post-operative): Swelling of right knee. Needle introduced, outer side of patella, no fluid obtained. Needle introduced inner side and about 55 c.c. of turbid fluid obtained, after which pressure evacuated a mucoid-like substance, the consistence of a skinned grape about 1 c.c. in diameter. Culture, no growth. Cabot splint. Temperature elevated practically since admission.

This patient has had a stormy convalescence. The amputation stump was very tender. His nerves were pretty well shattered and for several days it was necessary to dress him under Savariaud. The stump cleared up wonderfully under Carrel but has shown streptococcus hæmolyticus. The wound of leg also shows a hæmolyzing streptococcus.

July 30th: Stump wound clean. All joints primary union. Patient up and about on crutches. Uses knee, ankle and elbow without any limitation of motion. Physical condition very good.

Case XIII (June 17, 1918).—Knee; fracture patella; primary suture; gas gangrene. Operation secondary suture; success. Operation twenty-three hours after receipt of wound. Right knee penetrating wound by shell fragment; fracture of edge of patella; foreign body, 2 cm. long, 1 cm. in diameter, imbedded in patella. Joint filled with blood. Débridement; removal of foreign body; irrigation of joint with salt solution followed by ether; primary closure.

Calf; small wound; middle one-third; débrided, no foreign body.

Right hand; lacerated wound, comminuted fracture of fourth metacarpal; débrided and left open.

June 18th: Dressing in operating room with Savariaud anæsthesia about thirty-two hours after operation. Temperature, 102°; pulse, 112. Patient did not look badly. Region around incision of right knee-joint mouse colored over wide area 6 inches in all directions. On removing stitches considerable bubbles of gas. Gas gangrene smell. Wound widely opened. Joint itself distended with serum but no gas; reopened; wound edges excised thoroughly. Incision extended 6 inches upward on inner aspect of thigh and second long incision made on outer aspect of lower part of thigh; excision of devitalized muscles. Wounds and joint irrigated with peroxide. Carrel-Dakin treatment begun. Culture—Welch sporogenes-diplococci.

June 21st: Right knee: Carrel dressing in operating room with Savariaud. No local or systemic disturbance after reoperation. Patient encouraged to move knee June 23rd. No pus in joint. Granulations rapidly cleaned under Carrel.

June 25th: Few saprophytic, B. subtilis, B. mesentericus. Secondary suture right knee. Opening into joint closed with catgut. Skin freed and mobilized and sutured without drainage.

June 29th: Patient very comfortable. Wound on dorsum of hand looks clean.

July 11th: Wound of knee-joint firmly closed. Gentle massage, baking and motion. Free movement of patella.

July 30th: Gradual improvement under massage and hot compresses. Can flex knee to 45°. Walks without crutches.

February 7, 1919: Flexion to 90°.

March 11, 1919: Doing full duty.

Case XIV (June 17, 1918).—1. Left knee; shell wound shattering the patella into number of pieces. Operation twenty-three hours after receipt of wound. Transverse incision; débridement. Found necessary to remove fragments constituting patella. The joint irrigated and wound sutured wthout drainage.

2. Right knee; shell wound of soft itssues over patella. Joint not opened. Excision of tissues and wound left open.

3. Left ankle; shell wound of soft tissues over ankle. Excision of tissues and wound left open.

June 18th: Dressing; left knee distended. Right knee distended. Carrel dressing begun.

June 21st: Splint removed from left leg; patient encouraged to bend knee.

June 26th: Most of sutures removed. Patient upon crutches. Wound clean. Swelling has subsided.

June 28th: All sutures removed, wound clean. Patient can bear weight well and flex knee 30°.

July 11th: Patient has improved; can walk without cane. No pain. Flexion 45°.

January 22, 1919: Limited movement of left knee.

Case XV (July 19, 1918).—Perforating gunshot wound outer side right patella laying joint open. Wound 6 inches long. Joint opened about 2 inches. Operation six hours after receipt of wound. Excision of wound with complete débridement. Joint irrigated with saline and ether. Synovial membrane closed with continuous catgut. Capsule closed with interrupted catgut. Wound sutured with silkworm gut. Superficial infection; wound reopened and treated by Carrel-Dakin method. Secondary suture successful. Primary union. Function not recorded.

Case XVI (June 24, 1918).—Shell wound, penetrating, of right knee, with compound comminuted fracture of patella, impacted fracture of the femur in the supracondyloid region, and penetrating wound of the joint. Foreign body had been removed from wound by patient before first aid dressing was applied.

X-ray report; oblique fracture of right femur, lower third, with slight backward and inward displacement of lower fragments, slight overriding. Operation seven and one-half hours after injury. There was a large irregularly circular wound of entrance over the patellar

tendon, extending directly into the joint which contained a considerable amount of blood. The patella was broken into three large and many small fragments, and there was a small fissured fracture on the anterior surface of the femur between the articular surfaces of the condyles, which led upward to a V-shaped fracture at their base which was partially impacted. The fracture of the femur had evidently been due to direct violence without penetration of the bone by the éclat. After débridement of the wound of entrance, the joint was further exposed by curved external incision, extending upward through the capsule, and the torn synovia and fascia were further débrided. The joint was cleansed, after removal of a number of small fragments of the patella, by irrigation with a weak watery solution of iodine, followed by ether. The three main fragments of patella were preserved, and approximated by suture of the synovia and aponeurosis in such a manner as to close the joint. The skin wound was sutured. At the conclusion of the operation measurement of the limbs showed one inch shortening on the wounded side. A Thomas splint was applied and extension maintained. Primary healing of the wound. Fixation of joint and limb was necessitated by position of the supracondyloid fracture and fracture of patella. At the end of a month passive movements were begun. On evacuation, August 6, 1918, the wound was healed; there was ⅝ inch shortening and good union. At this time there was from 20 to 30° flexion. September 1, 1918, 10° flexion of knee. December 29, 1918, partial ankylosis of right knee; December 30, 1918, duty.

Case XVII (June 29, 1918).—Penetrating gunshot wound (45-calibre automatic pistol) of right knee, with comminuted fracture of patella, and fracture of lower border of external condyle. Operation after four and one-half hours. Accidental wound, ball entering over upper surface of patella, splitting it vertically, and passing backward, separating a thin layer of the articular surface of the external condyle, to lodge under skin at base of condyle.

X-ray report; comminuted fracture of patella. Comminuted fracture of external condyle of femur. Foreign body present; superficial on external surface, lower third of thig.h Lines of fracture apparently do not extend into joint.

Operation.—Two longitudinal incisions, one anterior, and one external. Débridement of soft parts; removal of bullet and small fragment of femur; irrigation of joint with iodine solution and ether; suture of aponeurosis and joint capsule; closure of soft parts and skin.

Continuous elevation of temperature after operation, swelling of joint and moderate pain. On June 2 sutures removed from anterior, and on June 3 from lateral skin wounds. Effusion persisted in joint, and on June 5, patient was etherized, and all sutures in capsule removed. There was infection of the synovial membrane, in addition to the soft parts. Two or three small fragments of bone were removed from the external condyle. The joint was irrigated, with ether, Carrel tubes inserted, and a Thomas splint reapplied. Cul-

ture from joint and wound showed streptococcus and staphylococcus. There was a moderate irregular elevation of temperature for a couple of weeks, the wound gradually cleaned under Carrel treatment, the general condition remained good, and the bacterial count was gradually lowered. The patient was evacuated August 9, the joint still open and granulating. Heard from about one month later, doing well, not yet healed. On October 4, 1918, record showed fibrous ankylosis of knee.

Case XVIII (July 30, 1918).—Perforating gunshot wound of left knee-joint, with fracture of both condyles. Operation after four hours. Wound accidentally received by discharge of rifle. Wound of entrance inner side of internal condyle; wound of exit large and ragged, at tip of external condyle. Had lost a considerable amount of blood, and a tourniquet was still around the thigh when admitted. There was paralysis and anæsthesia in the distribution of the external popliteal nerve.

X-ray report: Comminuted fracture of internal and external condyles of femur, with partial separation of external condyle; fragment displaced posteriorly. Line of fracture apparently extending into joint at internal border of external condyle. Several small fragments of bone lying free in soft tissues in close proximity to internal condyle.

Operation.—Ether anæsthesia, saline infusion at same time, and later intravenous saline. Long curved external incision, splitting the muscles attached to the external condyle, and elevating them from the bone, then carried across the aponeurosis, opening the joint to the outer side of the patellar tendon. Débridement of wound of exit, and partial excision of external condyle and of posterior surface of internal condyle. Wound of entrance débrided through a straight wound over internal condyle. All bone fragments removed, joint irrigated and closed, and primary suture carried out on soft parts and skin. The peroneal nerve was exposed during the operation and found undivided. The patient's condition was poor during and after operation, and later a blood-transfusion was given and followed by quick reaction. Evacuated August 10, 1918, still wearing splint, in good condition, and wounds healed. Result as to function not known; remaining March 31, 1918.

Case XIX (August 4, 1918).—Penetrating wound by shell fragment of right knee inner side of lower end of patella. No foreign body seen under X-ray. Joint fluid in considerable amount drained from wound. Operation eleven hours after receipt of wound. Complete débridement; joint irrigated with saline, then ether; synovial membrane and capsule completely closed; soft parts closed with rubber tissue drainage to the capsule. Joint infected; reopened; Carreled.

August 13th: Secondary suture by another surgeon who reported primary union. The knee could not be moved on account of compound fracture of bones of leg. Right leg; fracture of tibia and fibula. Through and through débridement. Fragments brought into good

position. Case report shows that one wound, presumably the fracture, was suppurating December 15, 1918.

CASE XX (August 8, 1918).—Perforating gunshot wound (German pistol) of left knee. Compound fracture of internal condyle of femur. Wound accidentally received while examining German pistol, probably 38 calibre. Wound of entrance inner side of left knee, base of internal condyle, ragged and surrounded by area of ecchymosis. Wound of exit midline, posterior surface, 4 cm. below lower border of popliteal space. Each 1 cm. in diameter. Joint slightly swollen. No injury to tibial vessels. General condition good.

X-ray report: No evidence of foreign body. A stellate line of fracture extending from upper edge of internal condyle downward and inward to joint surface.

Operation.—Débridement of wound of entrance through internal incision, and of wound of exit through posterior incision. Partial subperiosteal resection of internal condyle. Cleansing of joint, and suture of joint and wounds.

Moderate elevation of pulse and temperature after operation. No evidence of wound infection. On August 12th, wound inspected, and one suture removed; no retained secretion. Slight effusion in joint. August 13th, temperature 99°, no pain. General condition good. Primary healing of wounds. Evacuated August 23, 1918, wearing splint. September 22, 1918, flexion to three-fourths full range. To duty January 17, 1919, no class.

CASE XXI (August 22, 1918).—Penetrating gunshot wound (45-calibre automatic pistol) of left knee, with comminuted fracture of femur and tibia and penetration of knee-joint. Operation five hours later. Accidental self-inflicted wound of left knee. Wound of entrance on inner side of thigh 3 inches above joint, ½ cm. in diameter, marked deformity of knee, outward bowing, and hæmarthrosis. No injury to vessels or nerves.

X-ray report: Left leg upper third; foreign body superficial in from skinmark, size 45 calibre American. Left femur; comminuted fracture, perforating in character, extending from 2 inches above the internal condyle, downward and outward, apparently does not pass through the articular surface of the external condyle. Left tibia; linear fracture of the external tuberosity, with line of fracture extending into knee-joint.

Operation.—Two straight incisions were employed. One was on the inner side of the thigh 4 inches long, above the joint. The second, also 4 inches in length opposite to and below the knee, on the outer side. A limited subperiosteal resection of a small portion of the internal condyle was necessary, and showed that the ball had passed behind the joint at this point, while the knee was flexed, and had then perforated the outer tuberosity of the tibia from behind forward, separating a triangular portion 1½ inches in diameter, the base of which was formed by the articular surface. This was removed, a transverse incision extending forward through the capsule being added to the external incision. Joint irrigated. Internal wound

closed, with deep sutures of muscle, a small rubber tissue drain to bone. On the outer side the joint capsule was sutured, the gap left by removal of the section of the head of tibia being closed by turning over it a tongue-shaped flap of deep fascia. Cultures taken from the rubber drain the day after operation showed streptococci. On August 25th, two sutures were removed from the inner wound, and a few drops of pus evacuated. Slight effusion in joint, and slight elevation of temperature only. No pain. August 27th, slight temperature persists, serous drainage only from inner wound. Swelling of knee subsiding. Evacuated September 5, 1918; primary suture successful. One month later patient wrote from Base 20, reported as doing well, walking, still some stiffness of knee. To duty December 10, 1918, no class.

CASE XXII (October 20, 1918).—Perforating gunshot wound of left knee with comminuted fracture of the patella and external condyle of femur. Operation after seven and one-half hours. Soldier admitted with history that he had been wounded by sniper, while working on telegraph pole. One wound, probably wound of entrance, 1½ cm. in diameter over middle of patella; another wound 2½ cm. above upper internal angle of patella, of same size.

X-ray report: Left knee; comminuted fracture of patella. No evidence of foreign body.

Operation.—Transverse incision over middle of patella, embracing wound of entrance, and then curving upward along internal border of patella and quadriceps tendon, surrounding wound of exit. The outer two-fifths of the patella were comminuted, and were removed. The opening in the joint was freely enlarged by dividing the capsule and aponeurosis. An oblique fracture, splitting off the outer portion of the external condyle, with complete detachment of a portion of the cartilaginous surface ½ inch in diameter, was present. Several fragments of bone and cartilage with much liquid and clotted blood were removed. The joint was irrigated with Dakin's solution and ether. Layer suture of synovia, aponeurosis, and capsule. Skin wound not sutured. Joint remained clean. Passive movements begun before secondary suture of wound, which was not possible until November 16th, motion being rapidly regained, although there was slight limitation of flexion from light adhesions. There was considerable tension of the skin covering the anterior surface of the knee, after the successful secondary suture, and the necessary fixation during healing resulted in the reformation of a few adhesions, intra-articular, which limited the flexion to 20°. These were easily broken up under gas on December 6th, and he was evacuated the following day. Last examined December 25, 1918, was walking, flexion to about 40° and prospects good for complete functional recovery.

CASE XXIII (October 22, 1918).—Penetrating shell wound of left knee, with laceration of popliteal artery, and penetration of the knee-joint. Two foreign bodies retained. Operation after eight and one-half hours. On admission there was noted a wound in the median line on the posterior surface, left leg, on a level with the lower border of

the popliteal space. There was a history of hemorrhage after being wounded, which had required the application of a tourniquet, which was later removed. The posterior tibial artery could not be felt at the ankle but the anterior tibia could be detected pulsating.

X-ray report: Left knee; foreign body 3 by 5 mm. 50 mm. under skin with patella up. Another 1 by 2 mm. 70 mm. under skin. Larger foreign body appears to be in joint between articular surfaces, at a point about midway through the articular surface of femur. Smaller foreign body is at posterior portion of joint. Both foreign bodies appear to be free from articular surfaces.

Operation.—Hemorrhage recurred while patient was going under anæsthetic, and required the application of a tourniquet to the thigh for its control. A longitudinal incision was made in the midline popliteal space, and an opening in the popliteal artery 10 by 2 mm. uncovered. The artery was ligated. The smaller foreign body was found beneath it and removed. A perforation was found in the posterior ligament of the joint. The joint was then opened by anterior incision, and found to contain a considerable amount of blood. Careful and prolonged examination failed to disclose the second fragment, although ample exposure was obtained by cutting the external lateral ligament, and by partial excision of the external semilunar cartilage, and it was finally decided that it was imbedded in the crucial ligaments, and in view of its small size, might be left. The joint was irrigated, filled with ether, and capsule sutured, the skin wound not closed. No infection of the joint occurred, although the soft part wounds showed cocci in pairs and chains on count and culture. The circulation in the foot remained good, although the surface temperature was reduced for a time. Motion was begun after two weeks. Secondary suture was not made until November 26, when, two negative cultures having been obtained, a complete closure of the posterior and a partial closure of the anterior wound was successfully performed. There was a tendency for contraction of the popliteal wound, which required the application of weight extension for a time. Flexion was unrestricted, and the patient was evacuated December 12, 1918, with excellent prospects for functional recovery. Remaining March 31, 1918.

Case XXIV (November 11, 1918).—Perforating gunshot wound (machine gun) of right knee, with comminuted fracture of patella, and of condyles of femur, and division of popliteal artery and vein. Wounded while leading attack on machine gun nest on the afternoon of November 10. History of primary bleeding which did not require application of tourniquet. A Thomas splint had been applied soon after, and was in place on admission. Foot was cold, blanched and anæsthetic, no voluntary movement of ankle or toes, tactile sensation preserved, plantar reflex not present. General condition fair. Blood-pressure, 110; pulse, 100. Anterior and posterior tibial arteries not palpable. Wound of entrance over patella, small and punctate; wound of exit inner margin of popliteal space below condyle 1½ by 2½ cm. in diameter. Very marked hæmarthrosis. Shortening of limb

slightly over 1 inch. Tense swelling of leg to below middle of calf. Surface temperature of leg preserved.

X-ray report: Right knee; comminuted fracture through both condyles of femur; comminution of patella and bearing surfaces.

Operation (eighteen hours after receipt of wound).—Incision and débridement first made in popliteal space, through long longitudinal incision, exposing extensive ecchymosis of subcutaneous tissues, and a large clot in the popliteal space, the removal of which was followed by profuse hemorrhage. A tourniquet was applied, and the débridement continued. The popliteal artery was found completely divided, and the vein widely opened. Both were ligated. The internal popliteal nerve was contused but not divided. No evidence of infection. The joint was opened widely, and a T fracture of the femur found, as shown in the X-ray, with posterior displacement of the lower end of the shaft. Fragments of bone removed, with a portion of the end of shaft. Anterior incision opening joint, débriding wound of entrance and splitting quadriceps tendon, with partial division by right-angled incision of outer portion. Subperiosteal resection of bone fragments. Articular surfaces preserved. Irrigation of joint with hot water and ether, and closure of wounds in joint. Skin wounds not sutured. Condition after operation good. Some immediate return of circulation in ankle, but none in foot. Two days later it was evident that no return of circulation could be hoped for, and that amputation for impending vascular gangrene was indicated.

November 13th: Supracondyloid amputation of thigh, by antero- and postero-lateral skin flaps, utilizing previous incisions. Circulation controlled by digital pressure above. No evidence of infection. Skin flaps sutured back, and the face of the stump Carreled.

November 29, 1918: Secondary suture of stump. Wound edges excised, granulations pared, flaps dissected upward for three inches, and wound sutured after hæmostasis and irrigation. Aseptic healing, and officer evacuated to Saveney, December 30, 1918. Two weeks later walking on temporary prosthesis.

OPEN AMPUTATION THROUGH THE KNEE-JOINT

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Open amputation through the knee-joint for suppurative arthritis of the knee was first done at American Red Cross Military Hospital No. 2, at the suggestion of Colonel Joseph A. Blake. The patient had a badly infected joint with extensive burrowing of pus up the thigh. It was Colonel Blake's idea to avoid opening bone and marrow cavity to the infection. The result proved so satisfactory that it became the amputation of choice not only in infected knee-joints, but in other cases where formerly an open amputation through the lower end of the femur was practised. The writer has not been able to find more than a passing reference[1] to this operation in the recent literature of war surgery. It has therefore seemed worth while to report our experience.

We have done this operation in six cases, of which three for suppurative arthritis, and three for gangrene of the leg. Its advantages over open amputation through the lower end of the thigh fall under three heads: (1) less opportunity for bone and avoidance of marrow cavity infection in the stump; (2) improvement in the ultimate stump; (3) lessened operative shock.

1. We believe that danger and loss of time from bone infection in a stump is minimized by amputation through the knee-joint. It is evident that there is much greater risk from infection when the femur is sawn across, especially in the suppurating cases, than in amputating through the joint, which neither opens fresh bone channels nor the marrow cavity. In general, we have found that these stumps clean up quite satisfactorily, depending, however, on the amount of destruction of the cartilage, and the presence of osteitis in the condyles.

2. All the open knee-joint amputations require reamputation. As, however, many of the open thigh amputations require the same thing, with the alternative of an adherent terminal scar, it is not an objection. On the other hand, amputation through the knee-joint conserves the maximum amount of material for creating a long serviceable stump when the time for reamputation comes.

There is a further advantage with regard to obtaining the most useful stump, namely, that in a certain proportion of such amputations through the knee, the reamputation may be in the form of an osteoplastic between the patella and femur (Gritti). Of the three cases we have reamputated, this

[1] Kellogg Speed quotes notes on an inquiry carried out in England as follows: "Knee-Joint; amputation should never be performed through the knee-joint except as a temporary measure when necessary to save life." Journal of the American Medical Association, July 27, 1918, vol. lxxi, No. 4, p. 273.

procedure has been followed in two by Major Kenneth Bulkley, M.C. The first was entirely successful. Originally amputated for gas gangrene of the leg, the joint itself was never infected, and conditions rapidly became favorable for a clean secondary closure. It would seem that in a considerable proportion of similar cases this procedure could be carried out with great advantage to the patient.

The second case was still in course of treatment at the time of writing. He originally had a suppurative arthritis of the knee. Although apparently pretty well cleaned up at the time of the Gritti six weeks after open amputation, the end of the femur eventually sequestrated. X-ray at the time of sequestrectomy also showed some sliding and considerable absorption of the patella. However, it seems fairly probable that the patient will ultimately get union between the patella and femur. In the event that the patella has to be excised later he will still have a long thigh stump without a terminal scar. Whether or not a Gritti proves practicable after open amputation for suppurative arthritis must be determined from the ultimate result of this and other cases.

3. Amputation through the knee-joint can be done more quickly and involves less shock than thigh amputations. Not only is there no bone to cut, but the total of soft parts is reduced to a minimum. For this reason alone, we have preferred this operation in critical cases.

Case Reports.—Pvt. E. S. developed suppurative arthritis of the right knee-joint following a bullet wound received July 19, 1918. In spite of free lateral incisions he ran a septic course with pus burrowing up the thigh and down the leg, and six weeks after being wounded came to amputation. This was made through the knee-joint with comparatively little disturbance to the patient. The temperature soon became normal, the end of the femur, of which the cartilage was already largely destroyed by the suppurative process, granulated and cultures became negative for streptococci. Twenty days after the first amputation, a reamputation was done, the flaps were left open for secondary suture. The patient's temperature did not rise above 99½° F. following this last procedure, and he was evacuated in good condition a few days later.

Corporal C. W. suffered a compound fracture of the left leg by bullet on August 31, 1918. He was admitted five days later with gas gangrene of the calf, too high for amputation through the leg. He was amputated through the knee-joint with a long anterior flap. Twenty days later a Gritti amputation was done. Convalescence was complicated by an abscess in the stump. The patient was evacuated with the wound practically healed. Union had taken place between the patella and femur, and the patient could support a large part of his weight on the stump.

Corporal E. R. developed suppurative arthritis of the right knee following a shell wound of the joint and outer tuberosity of the tibia received July 27, 1918. Six weeks after wounding a resection of the

FIG. 1.—Sgt. M. P. Open amputation for infection and gangrene of the leg. (Photograph of colored drawing by Sgt. 1st-class Owens, M.D.)

FIG. 2. — Lieut. L. N. Gritti. Reamputation stump following open amputation for suppurative arthritis. Note the absence of scar over the end of the stump (the drainage opening is posterior) and the length of the stump.

joint was attempted, but the marrow cavity of the tibia was found to be infected, so an amputation through the knee-joint was done instead. The convalescence of this patient, who also had several other wounds, was rather stormy. He was evacuated before becoming ready for secondary amputation.

Sergeant M. P. was wounded in the back, left thigh and leg on September 9, 1918. He was admitted with paraplegia. Laminectomy and removal of shell fragment was done. An arteriovenous aneurism of the left popliteal space gradually became apparent. Ligation of the artery above the varix was followed by gangrene and infection of the leg. General condition was very poor. Amputation was done through the knee-joint, including removal of the patella. At present writing, some five weeks later, the patient's general condition has greatly improved. He is able to move the right leg well and the stump somewhat. The latter is cleaning slowly. It would have been better to have preserved the patella in this case with a view to ultimate osteoplastic reamputation, but at the time this possibility was not considered (Fig. 1).

Lieutenant L. N. developed suppurative arthritis of the right knee following bullet wound of head of tibia and joint on September 6, 1918. September 27, he was amputated through the joint. Six weeks later the stump seemed sufficiently clean clinically and bacteriologically for reamputation. An osteoplastic between the end of the femur and the patella was done. This was followed by sequestration of the end of the femur as described above (Fig. 2).

Private, colored, came to operating table in very poor condition with advanced gas gangrene of the leg. Amputation through the knee-joint was rapidly done. Death soon afterward. Had amputation through the thigh been attempted the patient would undoubtedly have died on the table.

The technic of the open amputation varies according to the local condition. As long flaps, especially anterior flaps, should be made as is feasible. The patella should be spared at the primary operation, whenever possible, on account of preserving the possibility of doing a later osteoplastic reamputation.

SUMMARY

Open amputation through the knee-joint, as opposed to open amputation through the lower end of the femur, offers the following advantages: fresh bone and marrow cavity are not exposed to infection; opportunity for a longer, and in some instances an osteoplastic stump; minimal operative shock.

GUNSHOT INJURIES OF THE KNEE-JOINT IN A BASE HOSPITAL

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At the base hospitals it was possible to keep for treatment, for a period varying from one to three months, patients who by necessity were evacuated from the evacuation hospitals in a few hours after their operation. The results of certain operative procedures, complications arising in special types of injuries as well as the probable functional results in these injuries, could therefore be observed at the base hospital. In this paper, gunshot wounds of the knee-joint will be so considered.

The primary operations in injured knee-joints were usually done at the evacuation hospitals where the policy of operative interference was fairly uniform. Through and through machine-gun bullet wounds of the knee without marked destruction of the articular surfaces were not usually operated upon. Hæmarthrosis or marked effusion into the joint in such cases was usually aspirated. Practically all penetrating and perforating wounds from high explosives were operated as soon as possible, the wounds of the soft parts débrided, foreign bodies and loose bone fragments removed from the joint, and the capsule of the joint closed if possible. If infection had already manifested itself or was probable, the joint was left open. Long oblique fractures into the joint were usually subjected to a débridement of the wound over the fracture and the joint was not opened. It was, as a rule, not possible to hold these cases at the front more than forty-eight hours, and they were evacuated with the joint immobilized in a Thomas splint to the base hospital, where they were held until complications were cared for and a definite convalescence established.

A group of such injuries in Base Hospital No. 13 will be considered from the standpoint of the original lesion, the type of operation performed at the front, the subsequent complications and their treatment as related to the function of the joint. Fifty-five cases had sufficiently good records for study. Forty-nine were operated at the front on an average of 1.8 days after their injury and of these forty-two were operated within twenty-four hours after injury. Of the whole group thirty-one or fifty-six per cent. remained uninfected after operation, and twenty-four or forty-four per cent. became infected. The influence of early operation in prevention of infection is instanced in the seven joints operated later than twenty-four hours after injury. Five became infected, the average time of operation being eight days after injury.

Infection is the most important factor in decreasing the ultimate usefulness of the joint. The type of injury to the joint, the post-oper-

ative treatment of the joint, and concurrent injuries to neighboring structures also play a rôle, but a less important one. The striking influence of infection on the function of injured joints is instanced by the results of examination of these cases on an average of three months after their injury. Of the thirty-one *non*-infected joints, twelve had normal motion and eighty-one per cent. had a range of more than fifteen degrees of active motion. Of the infected joints, five were amputated, and of the eighteen remaining only two had normal motion, and seventy-three per cent. had less than fifteen degrees of active motion.

Having seen the bad results of infection of the joint on its subsequent function, let us consider the relation of operative procedures employed at the front to subsequent infection of the joint.

In twenty-seven cases having a closure of the joint after operation at the front, sixty per cent. remained clean. Closure of the capsule alone leaving the soft parts open was the treatment in fourteen cases, and closure of the capsule and soft parts including skin was done in thirteen cases. Of the first group seventy-one per cent. remained clean, whereas only fifty-four per cent. remained uninfected where both the capsule and soft parts were closed. This points strongly to the advisability of capsule closure only, unless the patient can be held for observation.

In seventeen cases it was thought inadvisable or impossible to close either the capsule or soft parts after operation at the front, and the joint was left open. It is rather surprising that nearly fifty per cent. of these joints remained clean. This may be exceptional and surely presupposes a thorough débridement of the wound and revision of the joint.

Six cases were not operated at the front, five of which were perforating machine-gun bullet wounds of the knee-joint with no foreign body in the joint and with very little derangement of the joint. All of these remained clean and had splendid functional results, three having normal motion and two forty degrees of active motion after two and one-half months. One high explosive injury of the knee-joint was not operated at the front because it was thought the wound was simply one of the soft parts. This was in error and the joint became infected.

In the consideration of these operative procedures employed at the front in relation to subsequent infection of the joints, the most compelling facts are the importance of early operations in all high explosive wounds with thorough débridement of the wounds and revision of the joints, followed by capsule closure leaving the soft parts open.

The relation of the type of injury to the joint to subsequent infection and function of the joint will now be considered. Thirty-six patients had fractures of one or more of the articular surfaces of the knee. Twelve others had foreign bodies in the joint without gross injury to the articular surfaces, and in the remaining cases the joint was opened or penetrated without foreign bodies remaining in the joint or fracture of the articular surface.

The articular surface of the tibia was fractured alone in six cases. Four became infected following operation, and three of these were amputated following drainage of the joint that ineffectively controlled the sepsis. It is notable that of five amputations performed in this whole group of cases three were necessary in fracture of the tibia into the joint. The operative procedure employed in these cases at the front consisted in débridement of the wound over an oblique fracture of the shaft into the joint without opening the joint in four cases. Two of these became infected and required amputation. The two remaining uninfected had five degrees and fifteen degrees of active motion, respectively, seventy-five days after injury. Comminuted fracture of the head of the tibia was present in two cases and both became infected after opening the joint and removing loose bone fragments. One required amputation and the other had only five degrees of active motion after three months.

There were five patellar fractures from gunshot wounds. Two patellas were removed at the primary operation, both joints became infected, with ankylosis in one and amputation of the leg of the other for a Welch bacillus infection. In the three remaining cases the capsule of the joint was closed in one and the wound over the patella into the joint débrided and left open in two. These remained clean, and after three months from date of injury had a range of motion of fifteen degrees, twenty degrees, and normal, respectively.

Fracture of one or both condyles of the femur was the most frequent bone injury, occurring in sixteen patients. All were operated at the front. The capsule or capsule and skin were closed after débridement and revision of the joint in ten cases, sixty per cent. remaining clean. The joint was left open after primary operation in six cases, fifty per cent. remaining clean. Of the infected cases one required amputation and the others had only five to fifteen degrees of active motion three months after injury. Of the nine cases, seven, or seventy-nine per cent., had ninety degrees active motion, or better, and two had fifteen to twenty degrees of motion three months after injury. This marked variance in function of the knee-joint in the same type of injury emphasizes once more the deleterious effect of infection. It is also evident that fragments of the articular surface of the femur, in some instances amounting to nearly a whole condyle, may be removed without serious loss of function of the joint, provided that the joint remains clean.

Two or more bones entering into the articular surface of the knee were fractured in seven cases. After débridement and revision of the joint the capsule was closed in four, three of which remained clean. The joint was left open after operation in three patients and only one remained clean. The function in the infected joints was poor, ankylosis, or, at best, five degrees of active motion, being present, whereas in the uninfected joints two had ninety degrees or more and the others had

fifteen to twenty-five degrees of active motion three months after injury.

Twelve cases having no bone lesions had foreign bodies removed from the joint at the front, nine having a primary capsule closure and three being left open. Two-thirds of each group remained uninfected. The function of these joints differed in no way from those already tabulated.

The after-treatment of injuries, and especially infections of joints in relation to functions, has received marked attention since Willems, advocacy of Lucas Championniere and Rochard's principle of active mobilization of such joints. After thorough drainage, usually by lateral incisions and immediate mobilization of the joint by the patient's efforts, Willems contends that better drainage and much better function of the joint is obtained than by other methods of treatment. In 1918 he reported twenty cases of infections of joints of which thirteen eventually had practically normal motion. This treatment is in absolute contrast with the usual teachings regarding infected joints where immobilization for a long period has been the rule. Willems insists on mobilization immediately after operation.

The beneficial results of early active motion in non-infected joints is well supported by the experimental work of Phemister and Miller who removed the cartilage from the knee-joints of dogs with subsequent active mobilization of the joint. A new functional joint was formed in most instances and the articular surfaces of the bones were covered with new cartilage.

In the American scheme of medical organization, patients operated at the front during an offensive were evacuated to a base hospital as soon as possible, which was usually not later than two or three days after the operation. Knee-joints recently operated or injured were always immobilized as well as possible for transport. On arrival at the base hospital, the joints were not, as a rule, immediately mobilized, as they were very painful and the patient was tired and unwilling to actively move the joint. Injured knee-joints bore transportation poorly. Therefore, several days without active mobilization would pass and possibly at the end of that time another evacuation of the patient further to the rear was necessary. So in many cases arriving at the base, the joint had been immobilized by reason of necessity or circumstance for from one to two weeks. There were patients in whom active motion of the injured or infected joint was impossible or contra-indicated. Oblique fractures of the shaft of the femur or tibia into the knee-joint, extensive injuries of the soft parts in the region of the joint, long immobilization of injured joints with resultant restriction of motion and periarticular inflammation were generally contra-indications to the employment of active motion. Failure to obtain the patient's coöperation to actively move the joint occasionally occurred. It is also a question of judgment as to whether immediate active mobilization of a recently drained streptococcus in-

fected joint is advisable when the patient is septic. Personally, I do not believe it is and feel safer to wait forty-eight hours until the patient's temperature has fallen and his general toxic condition improved.

With these limitations we employed early active mobilization of injured or infected joints. At the beginning the patient was able to move the joint through about twenty degrees. Of the thirty-one uninfected joints, twelve had normal motion and sixteen others had over fifteen degrees of motion three months after injury, with progressive improvement in the latter group. It was necessary to drain thirteen knee-joints following gunshot injury at our hospital. We used long lateral incisions from the lower border of the patella to the upper limit of the subcrureal bursa, opening the bursa in its entirety. No drainage material of any kind was put into the joint. We were able to begin immediate active mobilization in only five cases. At the end of an average of forty-five days two had practically normal motion and all had twenty degrees or more motion in the joint. The other joints were immobilized because of previous long standing immobilization, fracture of the shaft of the tibia or femur, extensive wounds of the soft parts near the joint or periarticular inflammation and induration. The range of motion in these cases after an average of three months from the date of injury was under ten degrees. Though the function of these immobilized infected joints is poor, the well being of the patients was greatly improved after immobilization in several instances where misdirected efforts to obtain motion in the joints had resulted in a precarious general condition of the patient.

SUMMARY

1. Of the gunshot wounds of the knee coming to a base hospital after operation at the front, fifty-six per cent. remained uninfected and forty-four per cent. infected.

2. Of the infected cases, five required amputations, with one ensuing fatality.

3. Infection of the joint plays the most important rôle in decreasing the function of the joint.

4. Early operation at the front, thorough débridement of the wound, removal of foreign bodies and loose bone fragments from the joint, and closure of the capsule of the point are the most important elements in preventing infection of the joint.

5. Almost fifty per cent. of joints having fractures of the articular surfaces became infected after operation, whereas only thirty-three per cent. of other types of injury to the joint became infected.

6. Of the high explosive fractures of the condyles of the femur nearly sixty per cent. were uninfected after operation. Fractures of the tibia did not do so well.

7. Joints remaining uninfected after operation for fracture of the

FIG. 1.—Patient wounded October 9, 1918, over upper end of tibia by high explosive. On October 27th definite infection of the knee-joint. Knee was drained by lateral incisions. Because of continued sepsis amputation was done on November 29th. Specimen shows osteomyelitic cavity at upper end of tibia and destruction of articular cartilage of the condyles of the femur from infection.

FIG. 2.—Same patient, showing leg with lateral incisions into subcrural bursa and below the wound over the osteomyelitis of the tibia.

articular surfaces had normal motion, or ninety per cent. active motion in seventy per cent. of the cases.

8. Whenever possible, injured or infected joints were actively mobilized after operation, but active mobilization is not practicable in all war injuries of joints.

9. Of the infected joints, all that were by necessity immobilized had only ten degrees or less active motion two months after injury. Of those actively mobilized immediately after drainage of the joint, two had normal motion and the remainder better than twenty degrees of active motion two months after their injury.

FRACTURE OF THE ACETABULUM WITH INTRAPELVIC DISPLACEMENT OF THE FEMORAL HEAD

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Fracture of the acetabulum with central dislocation of the head of the femur is fortunately decidedly rare. Vaughan collected the cases reported up to 1912 and tabulated 26 clear cases and 39 doubtful ones. A very few have been reported since. Henschen, in two lengthy papers, discusses the traumatic and spontaneous (pathological) fractures of the acetabulum and devotes considerable space to its effects on the delivery of pregnant women. He records 169 cases, collected from the earliest records to the present time. Comparatively few of these are clean cases, however, since neither X-ray, operation nor autopsy proved the condition to be actual fracture of the acetabulum. Many cases have been so reported and subsequent X-ray findings indicated pelvic fracture instead.

Neuhof has described what he considers the juvenile form of acetabular fracture. In his case the fragments separated along their epiphysial lines, but without the femoral head being pushed into the pelvis. In this way it resembled the simple fractures of the acetabulum found in adults and can be reasonably considered as the juvenile form of the same condition. Greater trauma could easily reproduce the more severe adult type by forcing the head into the pelvis.

Halstead describes a case of central dislocation of the femur which resulted from a fall down a flight of stairs while under the influence of alcohol. The reduction was accomplished easily by manipulations similar to those employed in reducing a posterior dislocation of the femur, *i.e.*, the leg was flexed upon the thigh, the latter upon the abdomen, followed by internal rotation, circumduction outward, and extension. A plaster dressing was necessary to prevent recurrence of the dislocation. The ultimate result was good. Halstead recommends flexion with circumduction and extension to reduce the dislocation when the head has penetrated the acetabular floor; immobilization and extension in cases where the acetabular wall has been retained in front of the femur; and resection of the neck with removal of the head where the latter has penetrated the acetabular floor and cannot be reduced. He points out the possible dangers from manipulation, such as perforation of the bladder, intestines or blood-vessels by a spicule of bone.

Hitzrot presented, before the New York Surgical Society, a patient showing an unusual result of acetabular fracture. The man, aged thirty-two, had an injury to the left hip four months before. At the time of examination the left hip was ankylosed, the left trochanter more prominent and nearer the midline than the right, and a bony mass occupied the region of the great trochanter. X-ray showed a fracture of the acetabulum with displacement of the fractured floor into the pelvis. Bony repair had apparently taken place. The tumor felt between the trochanter and the ilium appeared as an ill-defined mass of bone.

At operation the trochanter was found capped with a mass of new bone which was also firmly attached to the rim of the acetabulum. The trochanter, together with

the mass of new bone and a small part of the ilium just above the acetabular rim, was removed with an osteotome. Movement of the femur was then free. The patient made an excellent recovery with constantly increasing movement at the hip. Hitzrot suggests that early motion might have prevented the ankylosis.

VAUGHAN, fifteen days after a fracture with central dislocation of the femoral head, exposed the head of the femur by an incision along the brim of the pelvis from the anterior superior spine to the femoral vessels, from which it extended downward and outward across the neck of the femur. Traction on the thigh and later on the exposed shaft at its junction with the neck of the femur, together with pressure on the head and rotation in all directions, was not sufficient to restore the dislocation. Only by inserting a lever from without and prying open the rim of the acetabulum was the head reduced. The rim was evidently fractured at the same time the floor gave way and opened, allowing the head to pass through into the pelvis, closing tightly again around the neck. The reproduction of the X-ray negative accompanying Vaughan's article gives the impression that the rim spoken of was formed by the floor of the acetabulum and not the true outer rim. The central portion of the floor was apparently pushed ahead of the femur and was pressed into place after the reduction. No retention or extension apparatus was used, as the dislocation did not tend to recur.

SKILLERN and PANCOAST report four cases, one of which was seen immediately after injury, the other three were seen eleven months to two and a half years later. The authors review the four cases and give a short bibliography, following which they discuss the nomenclature, etiology, mechanism, symptoms, differential diagnosis, prognosis, and treatment. They consider the usual etiological agent to be indirect violence, most of the patients having fallen from a considerable height upon the great trochanter. Direct violence occurs when the trochanter is struck by a heavy object. As to mechanism, the acetabulum is generally broken when the femur is slightly adducted. In other positions the femoral neck is more apt to fracture. In their opinion "the most important differential diagnosis is from contusions of the hip." In reference to treatment, emphasis is placed upon the necessity of determining if complications exist before proceeding with treatment of the fracture. They "would reduce the fracture, put the patient at rest in bed, and apply extension in the axis of the limb in conjunction with lateral traction upon the femoral neck." In a few days a cast would be applied, followed later by massage and passive motion.

In a second paper Skillern and Pancoast describe a patient of forty-five, struck on the left hip by a heavy weight. This caused a fracture of the iliac portion of the acetabulum, a fissure at the middle of the greater sacrosciatic notch, and a comminuted fracture of the head and neck of the femur, probably with impaction. Examination showed the legs of equal length and the left greater trochanter three-quarters of an inch nearer the symphysis than the opposite one. Manipulation was painful, but rotation was not otherwise impaired. The treatment consisted in manipulation for reduction and extension with lateral traction. Four days later a gypsum cast was applied. Recovery at four months was good except for some restriction in abduction.

ADAMS reported a case of fractured acetabulum, but without central displacement of the femoral head, in which there were no symptoms forty-eight hours after accident other than those due to the bruises received. Immediately after accident there was a slight limp, probably due to the mild pain on motion of leg and a hyperæsthesia over area supplied by lower sacral nerves. There was no evidence of fracture or dislocation and the condition was only recognized by X-ray. The recovery was complete.

BURNHAM, in a study of twenty-nine cases of fractured pelvis, mentions fractures of the acetabulum, but adds nothing new. However, he considers fully the fractures of the pelvis which are at times associated with injuries to the acetabulum.

FULLER discusses the subject of acetabular fracture quite fully and reports two

cases. The first, a man of twenty-nine, fell about thirty feet, striking the ground squarely on the bottom of the right foot, with the leg slightly abducted and the body inclined to the right. The right leg was shortened two to three cm. and slightly everted; all active motion at hip lost, but passive movement in all directions was possible. The lower portion of the abdomen was tense, tender and dull on percussion and the urethra was ruptured close to the bladder. Catheterization was successful after prolonged trial. The most striking sign was the sunken appearance of the great trochanter. X-ray showed the floor of the acetabulum fractured and the femoral head projecting into the pelvis.

Attempts at reduction by various manipulations under deep anæsthesia failed until the patient was placed flat on the floor and prolonged vigorous traction made laterally by a broad bandage placed around the thigh with the leg held vertically and strong traction made in this direction as well. With the return of the femur to its natural position, the leg assumed its normal length. Extension and counterextension were applied for one week, then a plaster-of-Paris cast for five weeks. The ultimate result was excellent—no limp, slight shortening, and almost perfect motion.

Fuller's second case was one in the service of Doctor Schiller. He was seen eleven months after injury, when he had ankylosis with the leg flexed, abducted and rotated outward. The patient is a cripple probably because the correct diagnosis was not arrived at promptly after the injury.

Schroeder reviewed the cases up to 1909 and reported three personal cases besides experimental work on the cadaver. His first case died in twelve hours. The second was treated by extension with a twenty-five-pound weight and an external splint for six weeks. Reduction was not accomplished, and at three months he was totally incapacitated. The third case required open operation, as reduction by manipulation failed. An incision was made above Poupart's ligament and about a quart of blood removed from a large hæmatoma situated beneath the abdominal muscles. The femoral head was then seen protruding into the abdominal cavity. The reduction was accomplished by flexion of the thigh upon the abdomen and slow adduction of the leg. Recurrence was prompt when the leg was extended and abducted. After reduction of the dislocation and a partial replacement of the fragments of bone the leg was fixed in extreme flexion, adduction and vertical extension, by plaster dressing. After five weeks the plaster was removed and active and passive movement begun. The final result was excellent.

The experimental work by Fox and Schroeder was performed on fourteen cadavers. In ten of these a five-pound hammer was used to strike the trochanter, with the leg extended and slightly adducted. Four fractures of the acetabulum, one impacted fracture of femoral neck, three fractures of the surgical neck and two fractures of the trochanter resulted. In four the blow was applied to the knee, producing a fracture of the femoral neck in each case. Schroeder points out that the force necessary to produce a fracture of the acetabulum must be applied suddenly, as a slow application will favor fracture of the pelvis instead. The author also discusses the mechanism, complications, infections, repair, age incidence, symptoms, prognosis and treatment.

Author's case of fracture of the acetabulum with unreducible intrapelvic displacement of the femoral head.

No. 7043. E. L., aged forty-eight years, admitted to the Surgical Service of the University Hospital May 29, 1917. Chief complaint, fractured right hip. Family and personal history negative.

Present Illness.—While working in a barn slipped and fell eight feet. He thinks he struck on his hip. Was unable to arise, but was without pain for about five minutes. Very severe pain then developed

FIG. 1.—Author's case of fracture of the acetabulum with intrapelvic displacement of the femoral head. Fracture also of ilium and of the ramus of the ischium. Fracture of ilium probably caused by great trochanter which is seen pressing against it. In original plate the femoral neck is shown to be uninjured.

in the injured hip. He was brought to the hospital about fifteen hours later and presented the following symptoms: Skin cold and clammy; pupils contracted by morphine; slight cyanosis of lips and ears; pallor of finger nails; heart irregular with blowing systolic murmur; abdominal muscles very tense; marked tenderness in lower right quadrant and over bladder; marked pain and limitation of motion in right hip; leg slightly abducted with one-half inch shortening; marked swelling over greater trochanter; pubic region very sensitive to touch; dried blood on end of penis and fresh blood appearing at meatus; complete suppression of urine. Blood-pressure: Systolic, 120; diastolic, 85.

The patient was X-rayed immediately, then placed in bed, Buck's extension applied and sandbags placed to prevent motion. He was referred to the Genito-urinary Surgery Department for the complete urinary retention which had appeared immediately after the injury.

Attempts at catheterization failed and a suprapubic cystotomy with insertion of a rubber tube was performed under local anæsthesia. The pelvic tissues were found œdematous and the bladder was very dusky. Free blood escaped from the bladder. Six days later an attempt at catheterization was again made and failed. Considerable bleeding from the urethra followed. The patient was then given a nitrous-oxide anæsthesia and the suprapubic wound enlarged by Doctor Loree. Retrograde catheterization was performed, using a soft rubber catheter, and a hard rubber drainage tube was inserted into the bladder. The latter was removed four days later, and the permanent catheter after a further four-day period. The suprapubic wound drained considerable urine at first and did not close until the thirtieth day. At this time a twenty-four French bougie could be passed without difficulty.

The *X-ray report* made by Doctor Van Zwaluwenburg is as follows: This is a badly shattered pelvis with the head of the femur driven directly through the acetabulum. There are at least two fracture planes in the os innominata: probably a separation at the articulation with the pubis; a fracture of the ramus of the ischium, and a disarticulation at its articulation with the pubis. These plates must be seen in stereo to properly appreciate the nature and extent of the injury.

The leg was held in abduction at an angle of about forty-five degrees, Buck's extension applied, giving a direct pull in this direction, and the foot of the bed elevated to give counter-traction. A second extension was placed around the thigh, close to the groin, and lateral traction made. The patient had little discomfort from the leg, but developed gastric distress with some abdominal distention and vomiting. Repeated gastric lavage and enemas overcame this. Bright blood and clots were passed for one week both from the catheter and the suprapubic drainage. The temperature ranged from 99 to 103, with occasional severe chills at first, until the twenty-sixth day. On the sixteenth day the extension had to be removed because of the development of bed-sores and was not reapplied. There had been no evidence of any reduction in the

dislocation of the femoral head through the acetabulum, and the patient's condition had not warranted any manipulative measures to effect a reduction for which extension and lateral traction had failed. An X-ray taken after the removal of the extension showed no improvement.

Under ether anæsthesia, July 7th, forty days after the accident, I manipulated the hip in all directions with evident separation of adhesions. The femur was rather strongly fixed in position, but with adduction, abduction, rotation, flexion and hyperextension, many adhesions could be felt giving way and the leg could be moved freely in all directions. It was impossible to extract the head of the femur from the pelvis with the amount of force which we could safely use, primarily because of the fractures both above and below the acetabulum, especially since the latter at time of accident had torn the urethra. After manipulation the shortening previously noted had disappeared.

The patient was discharged, on crutches, July 13th, with free passive motion in all directions, limited active motion because of some tenderness in hip, and with normally functioning urethra. He was advised to keep up both active and passive movements and not to bear weight on leg for three months. He was seen at that time and had free active movement in all directions except marked abduction, without pain and with no urinary disturbances. A letter the following January reported that he was walking without trouble and the urethra was still functioning properly.

Mechanism of Acetabular Fracture.—The experimental work of Virevaux and of Fox and Schroeder indicates that fracture of the acetabulum is most easily produced by a sharp blow on the trochanter with the leg slightly abducted (Virevaux) or slightly adducted (Fox and Schroeder).

Clinically, the same mechanism seems to prevail. Direct violence is very rare, as it is practically always due to a piece of shell or a rifle ball tearing away the acetabular floor.

Indirect violence, the usual etiological factor, is produced either by a blow upon the trochanter from some rapidly moving object or by a fall upon the trochanter, or, in exceptional cases, by a fall, striking on the bottom of the foot with the leg extended and slightly abducted. The condition of the acetabular floor probably plays a considerable part, a thin or diseased bone would naturally yield more readily. Normally the upper and posterior portion of the acetabulum are strongly developed while the inferior portion is comparatively thin. This would explain the more common occurrence of perforations when the leg is abducted, since in that position the force will be transmitted from the femoral head to the most delicate part of the acetabular floor. The action of the powerful hip muscles tends to push the femoral head into the pelvis if it has not already been driven through by the initial force.

Complications.—Hæmatomas due to laceration of large or small vessels by sharp bony fragments have frequently been reported. At times the peritoneum has been torn and the blood has entered the abdominal cavity

without the formation of a visible hæmatoma. The internal and external iliacs have been torn, constituting one of the most serious of the numerous complications demanding immediate diagnosis and treatment.

Any of the pelvic viscera may be injured and cases have been reported of wounds to the rectum, small intestine, urinary bladder, and urethra. Any of the nerves passing through the pelvis may be injured. It is extremely important that injuries to the blood-vessels, intestines, rectum, bladder and urethra be recognized at once and appropriate treatment instituted.

Signs and Symptoms.—1. History of a fall or blow on the hip or a fall striking on the feet with the leg extended and slightly abducted. Usually the trauma is great, but under proper conditions an insignificant force may produce the fracture.

2. Pain, usually severe, is complained of in the region of the hip. Passive movements generally increase the pain and active motion may be impossible because of its severity. Local tenderness is noted by palpation, especially over the trochanter when the force was applied at that point, and over Poupart's ligament and per rectum.

3. Loss of function: Motion may be normal, but as a rule flexion, adduction, abduction, and rotation are more or less impaired independently of the tendency to fixation caused by the pain. Motion in some cases, especially with the femoral head within the pelvis, is entirely lost. As pointed out by Fuller, the amount of motion will depend on the size and shape of the acetabular opening. If large, the motion may be interfered with to only a slight degree, while with a small opening motion may be seriously restricted. The arc of rotation of the femur is usually diminished.

4. Shortening: Slight shortening is generally present, but several cases, with central dislocation of the femoral head, have been reported in which no shortening occurred.

5. Flattening or depression of the trochanter: This is perhaps the most constant and important outward sign. Measurements from the trochanter of each side of the midline at the symphysis pubis will show a definite shortening on the injured side in about one-half the cases of acetabular fracture and in all cases in which the femoral head has penetrated into the pelvis. In these cases the fascia lata is found flaccid or relaxed (Allis' sign).

6. Position: The leg is usually in slight external rotation, occasionally with no rotation, and rarely in internal rotation.

7. Rectal examination: In central dislocation the femoral head can be felt protruding into the pelvis by rectal or vaginal examination. In simple fracture of the acetabulum, marked tenderness will be found on palpation. In some instances the femoral head can be felt in the pelvis by palpation above Poupart's ligament.

8. X-ray: Every case in which acetabular fracture might exist should have a röntgenogram. Only by so doing can some cases be diagnosed and only by this means can a positive diagnosis be made without operation or autopsy. The röntgenologist can show the presence or absence of a fracture

and the extent of the injury to the bony structures as well as determine definitely the location of the femoral head.

Differential Diagnosis.—The most common injuries which may be confused with acetabular fracture are: Contusion of the hip; fracture of the pelvis; fracture of the surgical neck of the femur; and dislocation of the femur. From the first the absence of a sunken trochanter and a normal rectal examination are usually sufficient. These two findings, together with absence of crepitation, aid in distinguishing fracture of the acetabulum from fracture of the femoral neck. Fracture of the pelvis cannot be distinguished by clinical signs alone, and the X-ray must be brought into use, as it must also be to positively differentiate the other condition just mentioned.

Prognosis.—According to Vaughan there were 30 per cent. deaths in the clear cases and 47 per cent. in the doubtful ones. With injury to the urethra, bladder, intestines, rectum or large vessels, the prognosis is exceedingly grave. In the uncomplicated cases the outcome, as far as loss of life is concerned, is quite favorable. Although the high mortality is largely due to the complications, some cases of acetabular fracture have died without demonstrable injury to other structures.

Even without complications or where these are successfully dealt with, the patients generally suffer permanently more or less from the fracture and dislocation. There is usually some limitation of motion with slight shortening and frequently considerable stiffness in the joint. In the majority of cases in which the dislocation was not reduced or in which it recurred the patients were completely incapacitated, and usually suffered from loss of motion, painful joints, lordosis, tilting of the pelvis and neuralgia from pressure on the obturator or other nerves.

Treatment.—First and most important comes the diagnosis and treatment of the serious complications. When these have been met successfully or where no complications exist the reduction of the dislocation must be effected if possible. The replacement of the femoral head in its natural position is usually accomplished by traction downward on the leg, outward on the thigh, plus adduction. By this method, using the outward traction as a fulcrum, the head may be withdrawn from the pelvis. In some instances slight abduction favored the reduction. Again none of these measures sufficed and marked flexion of the thigh on the abdomen together with outward traction effected the desired result. Each case must be treated as an individual condition and not by any fixed rule.

The difficulty in reduction of these fracture-dislocations is usually great. In no other joint injury are the muscular forces to be overcome so powerful. At times the acetabular floor closes about the femoral neck, making reduction by purely manipulative means impossible. Added to the mechanical obstacles we have potentially or actually the serious injuries to the soft tissues, necessitating the greatest care in manipulation and in some cases actually counterindicating any attempt at reduction.

Simple prolonged extension, both downward and laterally, with the leg

in slight abduction, has been used successfully a few times, but in the author's opinion the femoral head should first be reduced by manipulation if possible. Unfortunately the reduction is usually difficult and may be impossbile. In the latter case we have the choice of a radical operative procedure or manipulation to prevent adhesions and callus from interfering with the motion of the joint.

The operation may be performed to liberate the femoral head. This is necessary when it is held in the pelvis by the fragments of the acetabular floor pressing about the femoral neck. In this case an incision from Poupart's ligament outward to the trochanter, exposing the femoral neck and rim of the acetabulum, will allow the passage of a periosteal elevator or other suitable instrument along the neck of the femur and the elevation of the fragments of the acetabular floor. Lateral and downward traction should then effect the reduction. Opening the abdominal cavity may be necessary to treat various complications, but as an aid to reduction, as by pressing outward on the femoral head, it will be found of little service.

A more serious surgical procedure, resection of the head of the femur, has been mentioned by several authors, but no reference to the actual performance of such an operation was found. In view of the excellent results obtained by manipulation in the author's case it does not appear that the radical operation will be found necessary. However, in old fractures with bony ankylosis an operation to free the femur is indicated.

Manipulation is recommended in those cases in which the head cannot be reduced, either because of unsurmountable mechanical obstacles or where complications exist, as in the case reported, which preclude the possibility or at least the advisability of more strenuous measures. Manipulation, preferably under general narcosis, should be commenced as soon as the complications will permit. Motion should be obtained freely in all directions. In this way, adhesions will be broken up and callous bridging between the femur and pelvic ring will be prevented. Even after a lapse of several weeks manipulation may give comparative freedom of motion.

Fixation after reduction is essential in the majority of cases. This may be obtained by simple extension, the leg being kept either in marked adduction or marked abduction, or by the application of a plaster dressing. Frequent X-rays should be taken that any tendency for the displacement to return may be checked by suitable measures. Manipulation with moderate active motion is required after the removal of the fixation apparatus. Weight-bearing should not be tolerated for at least three months. Active and passive movements in all directions should be persisted in for probably a year.

Conclusions.—Fracture of the acetabulum with central dislocation of the femoral head has a high mortality and is fortunately rare. Depression of the trochanter and rectal palpation of the femoral head are important diagnostic signs, but every case should be X-rayed. Complications are frequent, severe in nature and demand immediate recognition and treatment. The successful repair of the fracture-dislocation depends much on its early diag-

nosis. Reduction by manipulation is recommended. Open operation is necessary only in the exceptional case or for the treatment of complications. Resection of the femoral head is unnecessary. Manipulation under general narcosis, when the dislocation is unreducible, has yielded excellent results in freedom of motion and capacity to use the leg.

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REPAIR BY AUTOGENOUS BONE GRAFTING IN FRACTURES OF LONG BONES

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Probably no class of cases occurring in the recent war has offered more important and interesting problems for solution than *gunshot fractures of long bones.* The frequency of wounds of the skeleton, and the varying conditions incident to the surgical care which each individual fracture demands, has placed this group of war injuries in the very fore-front for the most careful consideration. It must be remembered that all of these fractures are compound, and many badly comminuted, and in the cases I am herewith presenting as illustrations for this type of reconstruction, namely, Repair by Autogenous Bone Grafts, have suffered not only varying degrees of loss of bone substance, but in most of them a raging and often even an uncontrollable suppuration has already occurred, so that when they arrive they have not only non-union but widespread osteomyelitis and bone sinuses of the fragment ends, together with considerable loss of soft parts, either from large gutter wounds or perforating wounds of both soft parts and skeleton, showing marked explosive and destructive effects. These are indeed *truly complicated fractures* and call for the most exacting and skillful surgery.

THE TYPES OF FRACTURES CLASSIFIED

The classification of the fractures admitted at this hospital as to the various lesions caused by projectiles is somewhat indefinite. They are mostly of the comminuted type, but so at variance with the ordinary type of civil practice that seeing them at this late date, months after receipt of injury inflicting them, many are difficult to classify except to say that marked explosive effect is noted and much shattering and separation of fragments is seen. The cases reported in this series, however, show, in most cases, *solution of continuity of the shaft with loss of substance.* Accordingly I have grouped them as follows:

1. *Solution of continuity of shaft,* with loss of substance.
2. *Comminutions,* with widespread separation of fragments.
3. *Contact fractures,* with large fragments.
4. *Perforations of shaft,* associated with splintering. Member remaining in fair alignment.
5. *Gutters or grooves,* in which cases no apparent deformity or angulation is noted.
6. *Splintering fractures* into joints—involving and ankylosing adjacent joints.

* Authority to publish granted by the Board of Publication of the Surgeon General's office.

TYPES OF FRACTURES—HOW RECEIVED

1. *Solution of continuity of shaft,* with loss of substance. This condition has been noted in all of the long bones, tibia, fibula, femur, humerus, radius and ulna. More of these cases have occurred in the upper extremity than the lower. The humerus has been involved more often than the other long bones and more grafts have been used for the repair of this bone than the others. Tibia comes next. Such destruction or defects may be caused by any of the projectiles. High explosive shells and grenade fragments, as well as machine-gun bullets, have been the cause in these cases.

2. *Comminutions.*—This condition is said to be caused by projectiles travelling at a high rate of velocity, shell fragments, machine-gun bullets and grenade fragments, but the machine-gun bullet is responsible for a majority of the cases at this hospital.

3. *Contact Fractures.*—This type of fracture is usually caused by the projectile bringing about the fracture, which may be either transverse or oblique and may or may not be associated with large splinters of the bone. After inflicting the lesion, the missile becomes arrested by the shaft and frequently becomes imbedded at site of fracture, as very splendidly shown in one of the photographs shown here. (See Lieutenant Slaughter.)

4. *Perforations of Shaft.*—These perforations are usually caused by bullets which are supposed to have a low remaining velocity. Where there is complete perforation the bullet has a high velocity and there are noted longitudinal fissures radiating off. This condition has been noted quite frequently in some of the cases. In one case, that of an officer, both tibia and fibula were perforated, leaving only a small point of osteomyelitis (superficial) to be corrected. This has been done and the officer entirely recovered and discharged.

5. *Gutter and Grooves.*—Quite a common type of partial fracture of long bones and frequently have radiating fissures going off from point of injury. Many cases have been noted by X-ray findings.

6. *Splintering fractures* into joints—involving and ankylosing adjacent joints. This condition has been noted in quite a number of cases here, where the lower end of humerus has been splintered and elbow-joint involved, and head of radius likewise involving elbow-joint. Not only was there destructive process going on, but in one case, where there was an osteomyelitis of the head of the radius, which was operated upon by the orthopedist here, extended to and brought about a septic elbow, calling for resection of elbow.

Explosive Effect of Projectiles.—This has been exceedingly well shown in many of the cases of fractures produced by the type "perforation of shaft," principally machine-gun bullets, where large pieces of the shaft have been simply "blown out," with definite loss of three to four cm. of substance. This is clearly illustrated and well shown in several photographs of the humerus, radius, femur and tibia, and as the rate of velocity of the projectile plays such an important part in these cases I quote from DELORME the following,

which has bearing on this. He states that "When the velocity is excessive, free splinters are no longer carried along, but are violently thrown out in the form of a sheath. They no longer have any exact situation. They bury themselves in the soft parts at a more or less long distance from the tract, and some of them break out of the limb through numerous separate orifices." He further stated that "the dimensions of the splinters, like their number, are inversely in proportion to the velocity of the projectile, the less the velocity, the larger the adherent splinters and the less their number, and inversely." This explains likewise, in a measure, the widespread character of the osteomyelitis, for in many cases we find large-sized fragments or sequestra far removed from the site of bone injury, embedded either in the medullary cavity or in between fragments bridged over by callus, in many cases three or four inches away from the perforating fracture, and where there are many fragments caused by the splintering we invariably find just so many locations where osteomyelitis exists.

COMPLICATIONS

The most important complication to be considered in the late cases, apart from the *nerve lesions* and serious soft part damage, is *osteomyelitis,* which is found practically in all cases, and, in consequence, *latent sepsis,* which comes into play or lights up following operations for bone grafting, oftentimes many weeks after the wound has healed, and although it does not necessarily jeopardize the viability of the graft, provided the graft is held firmly and fits securely and the limb kept well immobilized, still there is great danger of failure. Therefore it is essential in all cases where a bone graft is required to allow a sufficient interval of time to elapse after the wound is healed before bone grafting is instituted.

1. *Tetanus.*—A complication to be seriously considered. The office of the Surgeon General has called attention to this in the following manner: "From the reports that are appearing in the literature it is evident that occasional cases of tetanus have developed following operations for old gunshot injuries. Even where tetanus antitoxin has previously been administered at the time of primary wounding, cases of so-called post-seric tetanus have occurred at a later period. To guard against this the Chiefs of Surgical Service and other operators are directed to have administered, 500 U. S. units of tetanus antitoxin forty-eight hours before operation on old gunshot injuries. This specially applies to such conditions as peripheral nerve injuries, ununited fractures, malunited fractures, osteomyelitis, etc."

"The specific directions we received at this Base Hospital were as follows: To avoid the dangers of hypersensitiveness, the patient should first be given a subcutaneous injection of 0.5 c.c. of serum diluted with 0.5 c.c. of salt solution, followed after five minutes by a second subcutaneous dose of 5 c.c. of serum. One hour later the intravenous injection of the full dose should be given. Injections should always be made slowly, with careful attention to the patient's condition, and the serum should be warm when injected.

Fear of anaphylaxis should never prevent the use of the serum when indicated. Careful technic and slow administration will go far towards avoiding serious accidents of this nature."

These above directions from the Office of the Surgeon General have been strictly complied with in every case of old gunshot wound before operation and no untoward symptoms have followed. Little else can be said regarding complications in general. To go into this subject fully would necessitate considering individual fractures of each of the long bones, and upon this subject much of great importance and interest will doubtless be furnished from the enormous number of cases resulting from the war.

DIAGNOSIS

There seems no need to take this up except to say that the X-ray has been our mainstay and chief guide. The careful studying of associated conditions, in every case obtaining a complete neurological report of the peripheral nerves, implicated both before and after operation, has been of exceeding benefit. Nothing to my mind is of greater importance than this, and the earlier proper physiotherapeutic treatment can be instituted, the better.

TREATMENT—PREOPERATIVE

Every care is given bone and joint casualties during the long period of waiting prior to the final operative repair work (grafting or what not), made necessary especially in those associated with slow-healing, infected open wounds, to avoid preventable deformities, muscular contractions, joint ankylosis in faulty positions, etc., in fact, every means is directed toward this conservation of function by means of suitable retentive splints, massage and proper physiotherapeutic treatment, together with diverting work and active exercise on the part of the man himself. It has accomplished excellent results in preventing avoidable loss of function or deformities in adjacent joints. If there is reasonable assurance in advance that ankylosis of a joint will occur, the best possible position for the ankylosing joint is determined upon, and the joint is fixed accordingly, and by application of splints, traction apparatus, plaster casts or other appliances to secure proper fixation and alignment of the fractured bone which will permit of the dressings and necessary care of unhealed wounds, *the function of the adjacent joints never being lost sight of*. The chief aim is to preserve as complete function as can possibly be attained. The patient after having had his antitetanic serum and his preoperative preparation comes to operation.

OPERATION

These are distinctly major operations. The work is not only difficult but hazardous and requires the most perfect technic and a *thorough grasp of regional anatomy*. Nothing is more important than constantly freshening one's mind on the regional anatomy and in this way keep a vivid impression

of the structures to be protected and those to be avoided. Blood-vessels must be kept constantly in mind and respected and the distribution and exact location (anatomical) and relations of the nerves must be remembered at all times. Indeed the preservation and protection of the latter causes me more anxiety than any other steps in the operation. Especially true is this in grafting the humerus, for fear of wounding the musculospiral nerve.

Regional Considerations. A. *Upper Extremity.* 1. *Humerus.*—In doing an autogenous bone-grafting operation on the humerus, the following structures are to be avoided. In preparing field for either an intermedullary or inlay graft in the upper third posteriorly and above, the definite location of the circumflex nerve must be borne in mind and protected from injury.

In the middle of the shaft and posteriorly and to the outer side, the musculospiral nerve.

Internally the ulnar and median nerves and the brachial vessels. The best incision is anterio-external, as the exposure for a greater distance can be here made with least danger to the musculospiral nerve which is the principal strucutre to be avoided.

2. *Ulna.*—The incision of choice is posterior in both upper and middle thirds.

3. *Radius.*—The placing of the incision is on the radial or outer border of forearm.

B. *Lower Extremity.* 1. *Femur.*—The best incision and the most logical one for reaching any portion of the shaft of the femur is on the outer aspect of the thigh. This incision admits of freely uncovering and delivering the fragments into the wound with the least danger to the important structures, and the incision can be safely made as long as desired without serious damage, barring infection.

2. *Tibia.*—The incision of election is on the anterio-internal surface and it can be made the full length of the bone without damaging any important structures.

3. *Fibula.*—The best incision for uncovering this bone is external. The principal nerve to be avoided is the superficial peroneal nerve.

TREATMENT—POSTOPERATIVE

Regarding the postoperative treatment, the same principles apply as for preoperative treatment, and as soon as justifiable, the patient is given the benefit of the efficient services of the reconstruction aids. Just here should come a word of caution, namely, that at the beginning of treatment by reconstruction the greatest care possible is to be observed by them in their handling and manipulation, to avoid any damage to the early fragile callus that necessarily is slow in forming around these grafts, especially where the loss of substance in the shaft of the long bones has been extensive, requiring a long graft to bridge across the gap. I call attention especially to this in view of the fact that in one case of graft of the humerus the graft had to be 7¼ inches long to fill in the defect. All went well in this case and complete union

had occurred, external splint removed, and after a few treatments were given pain was complained of, and on further X-ray examination a fracture of the graft was noted in the distal socket of the lower fragment. The line of fracture was well within the inlay of the lower fragment and completely surrounded by new bone formation (callous), so that the case will probably not be seriously retarded.

PERIPHERAL NERVE INJURIES COMPLICATING FRACTURES

Just a word regarding this complication. The policy pursued here is to attend to the fracture (correct the non-union by bone graft), and, in consequence, in those cases where there was not a complete anatomical division of the nerve it is observed that it is often freed from its scar tissue and restored, for, as is well known, the nerve trunk has in the majority of cases not sustained a primary injury, but has been exposed in a greater or less degree in the wound of the soft parts incident to the wound of the skeleton. In such cases where there has been grave infection and osteomyelitis, the process of healing has been much delayed, and the dense cicatricial tissue resulting impinges upon the nerve, and it is actually caught in the midst of this fibrous mass and its blood supply, due to the progressive contraction, is diminished and the nerve is strangled and becomes functionless. Operation frequently frees the nerve and there has been in many cases complete restoration of function following the same. The first operation of autogenous bone grafting done at this hospital was done by the writer on August 20, 1918, and illustrates this very important point. It is incorporated in this series of cases. It was a graft taken from the tibia to repair a non-union of the humerus, of four or five months' standing, with a completely paralyzed arm with definite musculospiral involvement. Almost immediately following the operation the paralysis began to improve and the patient was returned to duty in two months with an arm thoroughly united and the nerve function completely restored. The report of this case with its pictures is the fifth case here reported. A brief history of these cases with their radiographs, before and after operation, and in some few a photograph of the ultimate result, is appended. There are twenty cases in all, and all, save one, done for non-union following gunshot wounds and fractures, with loss of substance in many.

The writer agrees with the following remarks of GROVES (*British Jour. of Surgery*, 1918–6, 203), quoted from notes in *Review of War Surgery and Medicine*, and issued by the S.G.O. He believes "it bad surgery to remove any attached fragment from a comminuted fracture and doubly bad to cut off the ends of the main fragments, because in throwing off infections they also throw out reparative callus." As the osteoblast is the bone-building cell, the more bone saved the more chance of bone proliferation, and as bone will be manufactured out of fibrous tissue of the periosteum or other structures, marrow or what not, it is wise policy to leave as much bone as possible, in order that the graft will aid in the bone formation.

SUMMARY OF CASES

From the large number of fracture cases thus far received at this hospital, twenty have been selected for grafting. There are a number of additional cases, however, awaiting bone repair, but as yet they are not in condition for grafting.

In two of these cases the graft did not retain its viability. Attention to this is noted in the case histories. The other cases have been so far universally satisfactory. The case histories are appended, with illustrations.

One other case of interest is likewise appended at the end of this article with its case history.

Case I. Autogenous Bone Graft. Humerus.

J. M., Pvt., Co. C, 52d C. A. C. Age, twenty-three years. Date of admission, March 8, 1919. Date of injury, November 12, 1918. Date of operation, March 14, 1919.

Diagnosis—

Old, compound, comminuted fracture, left humerus, middle third. Absence of bone shaft for a distance of 1 cm. Incurred by accidental explosion of shell in Camp, Verdun Sector, November 12, 1918.

Operation—

Resection humerus, left. Five inches graft taken from tibia, left. Inlay. Incision on antero-external to outer side of biceps muscle. Point of non-union uncovered. Periosteum incised to full length of incision and stripped back from shaft both above and below seat of fracture. Inlay out with Albee saw and prepared for graft, which was taken from tibia and fixed by kangaroo tendon.

Operators—

Major Frank Martin, Lieutenant Hatch, Lieutenant Fields.

Remarks—

Wound healed under one dressing. Still in cast.

Result—

June 4, 1919. The cast has been removed. X-ray examination reveals complete bony union and arm in perfect alignment. There was evidence in this case upon entrance of a peripheral nerve lesion, probably a complete anatomical division, principally involving the musculospiral nerve.

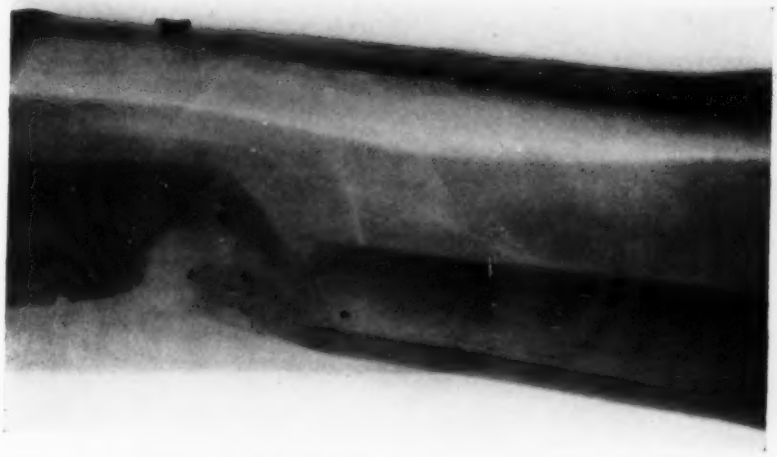

FIG. 1.—Case I. Before operation.

FIG. 2.—Case I. After operation.

Case II. Humerus.

F. G., Pvt., Co. E, 141st Inf. Age, twenty-nine years. Date of admission, December 29, 1918. Date of injury, October 7, 1918. Date of operation, January 7, 1919.

Diagnosis—

Fracture, old, comminuted, humerus right, ununited at junction of upper and middle third. Result of G. S. W., shrapnel, received on Champaign Front, France, October 7, 1918. (Loss of substance, 1½ in.)

Operation—

Open operation, spongy bone at end of both upper and lower fragments removed for distance of about 2 inches in order to get down to solid, healthy bone. Medullary bone graft 7 1/3 inches long taken from right tibia and inserted firmly in medullary canal of upper and lower fragments.

Operators—

Major Frank Martin, Captain Brothers.

Remarks—

Wound healed under one dressing, slight evidence of callus at the insertion of the graft into both upper and lower fragments in one month. On April 25, 1919, splint removed and union firm. He was taken over by the Reconstruction Aides for massage treatment. Some slight pain was noted at lower end of arm after a few days of massage, and upon X-ray examination it was found that a fracture had taken place at the lower insertion, but callus was developing all around and holding the graft fairly well, so a case was reapplied.

Note—

June 4, 1919. Good, firm, bony union has occurred in this case at both ends of the long graft. It has not completely bridged across this large gap, but is progressing satisfactorily, his forearm and hand have recovered full strength and the psychological peripheral nerve lesion of the musculospiral nerve has entirely recovered. Upon entrance he had a very definite wrist drop. This has entirely cleared away, as will be seen from the photograph of the patient's arm. There is a serious disturbance of the soft parts, as is clearly shown by a deep-gutter wound on the anterior aspect of arm, and the muscles at this site have been seriously damaged and the impairment of function incident to this will be slow in returning.

FIG. 3.—Case II. Before operation.

FIG. 4.—Case II. After operation.

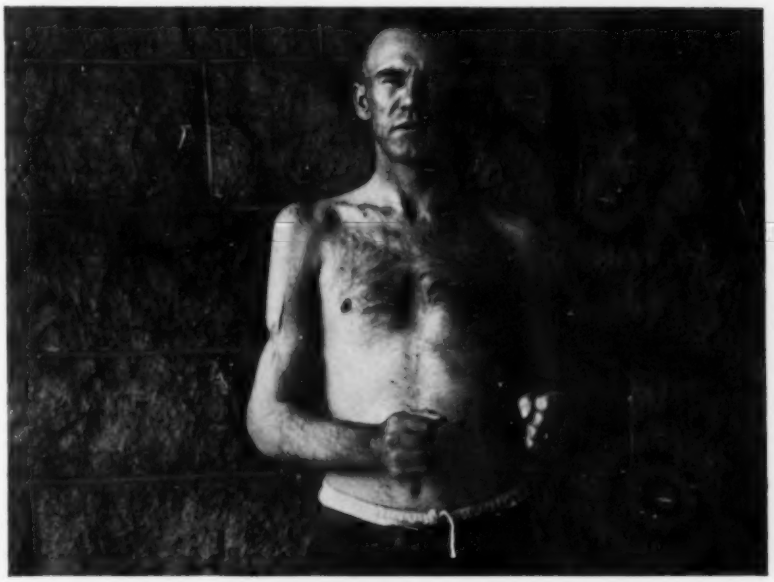

FIG. 5.—Case II. Ultimate results.

Case III. Humerus.

E. A., Pvt., Co. M, 41st Inf. Age, twenty-nine years. Date of admission, January 25, 1919. Date of injury, October 6, 1918. Date of operation, February 20, 1919.

Diagnosis—

1. Fracture, ununited, compound, old, lower third humerus right, with loss of about 1 inch of bone.
2. Osteomyelitis, chronic, mild, of ends of fragments.

1 and 2 result of G. S. W., M. G. bullet, received in action in Argonne Forest, France, October 6, 1918.

Operation—

Bone graft. Piece of bone 5 inches in length taken from right tibia. One end placed securely in medullary canal of lower fragment and the other fastened in groove prepared for same in upper fragment by means of kangaroo tendon.

Operators—

Major Frank Martin, Captain Brothers, Lieutenant Hatch.

Remarks—

Healed under one dressing.

Result—

(At end of six weeks.) Light case still on. X-ray shows graft viable and callus forming satisfactorily.

Note—

June 4, 1919. Case has been removed, arm is getting stronger each day. There is now good bony union, with improvement as to function of joints (especially elbow) noted from day to day. On entrance this patient had evidence of peripheral nerve lesion (musculospiral). Evidence principally wrist drop. At present writing this has entirely cleared away. X-ray report shows callus formation going on entirely satisfactorily.

FIG. 6.—Case III. Before operation.

FIG. 7.—Case III. After operation.

Case IV. Humerus.

J. A. H., Pvt., Co. A, 355th Inf., 89th Div. Age, twenty-three years. Date of admission, February 17, 1919. Date of injury, November 4, 1918. Date of operation, April 8, 1919.

Diagnosis—

Compound, comminuted fracture, humerus left, upper third, slight fibrous union, loss of substance. Incurred in action on Verdun Front, France, November 4, 1918, by M. G. bullet.

Operation—

Autogenous bone graft 6 inches in length, humerus left. Graft taken from tibia left.

Operators—

Major Dickson, Captain Adams, Captain Kauffman.

FIG. 8.—Case III. Before operation. Showing splint worn from over-seas.

FIG. 9.—Case III. After operation. Ultimate result.

Result—

Undetermined. Progress satisfactory. Still in cast.

X-ray Findings—

Before operation: Old comminuted fracture of the left humerus at the junction of the upper and middle thirds. Moderate amount of angulation backward and upward. Absence of the shaft of the bone a distance of 6 cm. The interval is bridged across by a formation of callus 1 cm. in diameter, which has been fractured. No other callus formation.

X-ray Findings—

After operation: Bone graft of the left humerus. Slight angulation inward at upper end of graft. Otherwise fragments are in good condition. Shoulder-joint appears normal.

FIG. 10.—Case IV. Before operation.

FIG. 11.—Case IV. After operation.

Case V. Autogenous Bone Graft. Humerus.

C. H. B., Cpl., Gas Defense, M. O. T. C. Age, twenty-four years. Date of admission, July 10, 1918. Date of injury, March 1, 1918.

Diagnosis—

1. Ununited fracture, humerus, left, at middle of middle third.
2. Entire paralysis of left arm, with complete musculospiral involvement.

1 and 2 accidentally incurred by being struck by motorcar at Kansas City, Mo., March 1, 1918.

History—

Patient treated in Kansas City, on admission, ununited fracture was noted, with paralysis.

Neurological Report—

The slight hemianæsthesia left is undoubtedly psychic, as there are no other symptoms of an organic nature.

There seems little question about the brachial plexus involvement, as the area of nerve supply from the plexus is involved, —viz.: Sensory motor and resulting atrophy; whether the brachial plexus involvement was primary at time of accident or secondary to pressure from cast from an ascending neuritis from musculospiral involvement at seat of fracture is not known, as the soldier was not examined until some weeks after the accident, when the prominent features were wasting of pectoral, scapular and shoulder-joint regions, making it appear as if there were damage to the plexus proper rather than secondary to trauma lower down. There seems to be reason for bone graft, and at same time musculospiral will be exposed, which, if found injured, can be remedied, but it is believed most of trouble is higher up in plexus.

Date of Operation—

August 20, 1918.

Operation—

Open operation, fixation of fragments by autogenous bone graft, removed from tibia, inlay, Albee saw, fixed with kangaroo tendon.

Operator—

Major Martin; Assistant, Lieutenant Sharpe.

Result—

Healed under one dressing and made an uninterrupted recovery.

Ultimate Result—

Complete restoration of all the peripheral nerve lesions and patient sent to duty October 5, 1918, with an excellently united fracture and perfect function of arm.

FIG. 12.—Case V. Before operation.

FIG. 13.—Case V. After operation

Case VI. Autogenous Bone Graft, Humerus.

T. D. G., Pvt., Co. 461, M. T. C. Age, twenty years. Date of admission, April 11, 1919. Date of injury, February 12, 1919.

Diagnosis—

Fracture humerus right, simple, junction of middle with upper third. Accidentally incurred while riding motorcycle. Ran into a horse which came out on road from a bypath, at Libourne, France, February 12, 1919. Entered here with ununited fracture humerus right.

Date of Operation—

May 2, 1919.

Operation—

Bones delivered by Lane forceps through an anterio-lateral incision. Fragments freshened by sawing off the fibrous ends. Inlay cut with Albee saw, and graft, six (6) inches, from tibia. Plaster cast applied.

Operator—

Major Frank Martin, M. C. Assistants: Captain Brothers, M. C.; Lieutenant Hatch, M. C.

Remarks—

Wound healed under one dressing.

Result—

Case removed June 3, 1919 (just 32 days following operation). (See X-ray marked "After operation.") Callus has already formed, bridging across gap, incorporating graft, and giving firm bony union and excellently straight skeleton, with fragments in perfect alignment. There is no loss of function whatever in this case. Having been immobilized for so short a time, the joints and muscles have not been impaired in the least, and he has full use of shoulder and elbow.

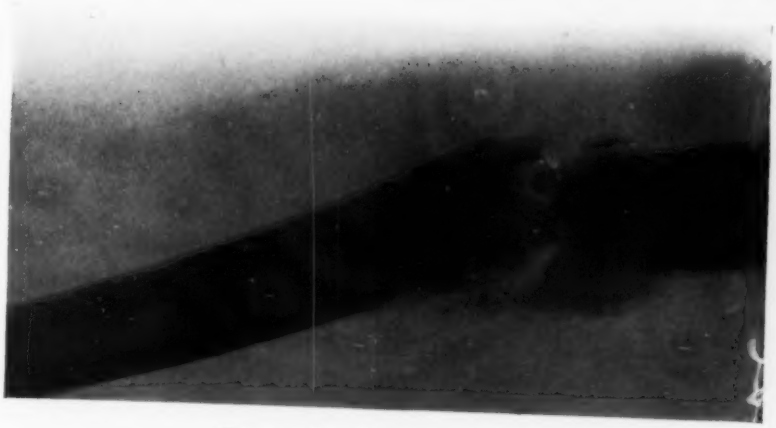

FIG. 14.—Case VI. Before operation.

FIG. 15.—Case VI. After operation.

Case VII. Radius.

W. H. P., Pvt., Co. C, 117th Sig. Bn. Date of admission, January 27, 1919. Date of injury, September 22, 1918. Date of operation February 7, 1919.

Diagnosis—

1. Fracture, ununited, old, lower third radius, right, with loss of about 1 inch of bone.

2. Subluxation, downward and externally, of ulna on carpus. Lower fragment of radius firmly fastened to ulna by callus. 1 and 2 result of G. S. W., high explosive, received while in action at St. Mihiel, France, September 22, 1918.

Operation—

Lower fragment of radius dissected free from ulna. Sliding graft taken from upper fragment of radius and inserted in groove, both fragments, and fastened with kangaroo tendon. Case applied.

Operators—

Major Frank Martin, Captain Brothers, Lieutenant Hatch.

Remarks—

The bone-grafting operation in this case was done in tissue which still showed evidence of osteomyelitis so that graft did not remain viable. It was left in place, however, as scaffolding, and X-ray pictures indicated that callus was forming around it. At any rate, there was some osteogenetic process going on. It was finally removed and the arm still kept in splint to maintain supination.

Result—

The ultimate result in this case undetermined. Wound (at this date) nearly healed. Whether another graft will be needed later cannot at this time be determined. So much apparent callus is seen in the last X-ray plate that there is a possibility that further operation may not be needed.

FIG. 16.—Case VII. Before operation.

FIG. 17.—Case VII. After operation.

Case VIII. Radius.

W. C., Pvt., Co. G, 127th Inf. (Overseas.) Age, twenty-two years. Date of admission, December 29, 1918. Date of injury, August 31, 1918. Date of operation, January 24, 1919.

Diagnosis—

1. Fracture radius, left, compound, comminuted. Entire middle third blown out. 2. Peripheral nerve lesions musculospiral and ulna, involved at site of wound, middle forearm. 3. Big gutter wound, healed, involving inner and lateral surface of forearm. 1, 2 and 3 incurred while in action near Soissons, France, by M. G. bullet. Interval of time from receipt of wound to admission in hospital, 4 months. Interim after admission before operation, 26 days.

Operation—

1. Open operation bone grafting. Bone delivered and showed extensive osteomyelitis. Graft 5⅛ inches taken from tibia, left.

Operators—

Major Frank Martin, Captain Brothers, Lieutenant Hatch.

Neurological Report—

The ulnar nerve has escaped, the poor functioning of muscles supplied by it being due to interference from surgical causes. The radial branch of the musculospiral has been completely divided, but several filaments of this nerve are still active, as will be mentioned below, these filaments coming off above the site of the lesion. Extension is lost on this account, as also on account of the fact that extensor muscles have been directly divided. There has also been complete division of the median nerve, anatomical in character, with paralysis of its muscle of supply.

There is fixation of the wrist-joint as a result of tendon contraction. Both pronators of the wrist have been directly injured. The fingers are in a position of extension, due to paralysis of the deep and superficial flexors of the fingers; the extended fingers can be slightly flexed; this, however, due to action of the interossei. All the thenar muscles are paralyzed with exception of the adductor of the thumb, which is, however, weak from disuse. All the extensors of the wrist and hand are paralyzed with the exception of three muscles, *i.e.*, the extensor ossis metacarpi pollicis, the extensor indicis and the extensor minimi digiti; the action of these three muscles combined with that of the interossei and the two inner lumbricals performs the limited motions which are present in the wrist and hand.

FIG. 18.—Case VIII. Before operation.

FIG. 19.—Case VIII. After operation.

Prognosis—

Poor for practical functioning of this hand; active and passive massage will undoubtedly do some good; an attempt should be made to restore median nerve function by surgical means, remembering that this member has been in a splint for a little over seven months. (Captain Fischbein, M.C., neurologist.)

Result—

Wounds healed under one dressing. The operative wound of the forearm was necessarily made through considerable scar tissue in consequence of very deep long gutter wound of soft parts, received at same time and by same projectile that blew out his radius.

This is mentioned for the reason that where the operative incision has to be made through such dense scar tissue it frequently breaks down, but there was nothing of the kind in this case. Inspection of the photograph of the X-ray plate following operation will show very excellent alignment and the two bones lying parallel. The nerve complication has considerably improved, but there still is definite evidence of an anatomical nerve lesion.

FIG. 20.—Case VIII. Operation.

FIG. 21.—Case VIII. Operation.

Case IX. Radius.

G. L. H., Pvt., Co. 3, 3d Bn., 164th D. B. Date of admission, March 4, 1919. Date of injury, October 12, 1918. Date of operation, March 12, 1919.

Diagnosis—

1. Fracture, simple, old, mal-united, upper third radius, left. 2. Fracture, simple, old, united, upper third ulna, left. 1 and 2 accidentally incurred while wrestling at Camp McArthur, October 12, 1918. Operated at Camp McArthur. Ends of radius were brought together and fastened with kangaroo tendon, which failed to hold bones in place.

Operation—

Sliding bone graft on radius left. Inlay taken from lower fragment and fastened in place with kangaroo tendon. Plaster cast applied.

Operators—

Major Frank Martin, Captain Brothers, Lieutenant Hatch.

Result—

Good, firm, bony union and perfect alignment, with strong callus formation. (May 11, 1919.)

FIG. 22.—Case IX. Before operation.

FIG. 23.—Case IX. After operation.

Case X. Radius.

R. B. R., Pvt., Co. A, 10th Am. Tr. Date of admission, January 13, 1919. Date of injury, December 20, 1918. Date of operation, January 15, 1919.

Diagnosis—

Fracture radius right, simple, junction of lower and middle third, with resulting malunion. Accidentally incurred while cranking auto truck at Detroit, Mich., December 20, 1918.

Operation—

Open operation bone graft with sliding inlay method. Cast applied.

Operators—

Major Frank Martin, Lieutenant Hatch.

Remarks—

This patient made an uneventful recovery. Wound healed under one dressing. Firm union developed in about six weeks.

Result—

Eminently satisfactory. Firm union and perfect alignment. Last X-ray picture shows considerable callus formation.

FIG. 24.—Case X. Before operation.

FIG. 25.—Case X. After operation.

Case XI. Radius.

G. J., Pvt., Co. E, 353d Inf., 89th Div. Age, twenty-five years. Date of admission, March 11, 1919. Date of injury, November 5, 1918. Date of operation, April 4, 1919.

Diagnosis—

Compound, comminuted fracture, radius right, 6 cm. above wrist-joint. Loss of 4 cm. of bone. Incurred in action in Argonne Forest, France, November 5, 1918, by high-explosive fragment.

Operation—

Resection of ends of fragments, radius right. Autogenous bone graft taken from tibia right, 6 cm. in length. Fastened in groove of upper fragment and in medullary canal of lower fragment.

Operators—

Major Frank Martin, Captain Brothers, Lieutenant Hatch.

Remarks—

Wound healed under one dressing. As will be seen from X-ray plate, he has perfect alignment and satisfactory callus formation going on.

Result—

June 3, 1919. Both wound in arm and leg healed primarily under one dressing, and as will be seen from X-ray picture marked "After Operation," there is perfect correction of skeleton and excellent alignment, good, firm, bony union has occurred and patient is fast regaining complete function of hand and arm.

FIG. 26.—Case XI. Before operation.

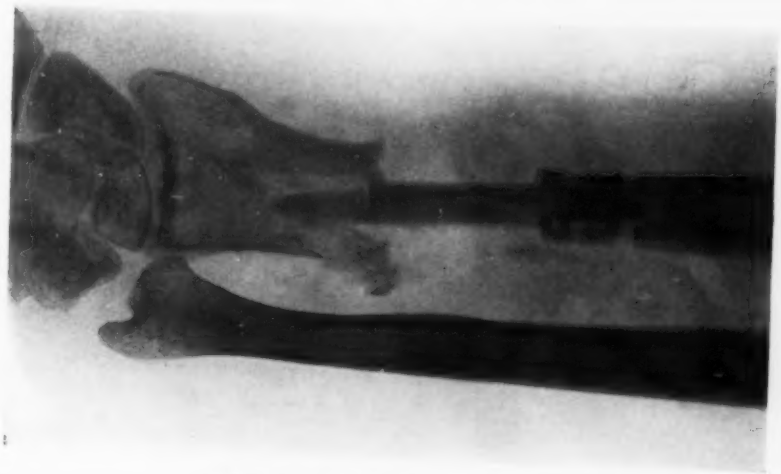

FIG. 27.—Case XI. After operation.

Case XII. Ulna.

L. F. J., Pvt., Co. E, 354th Inf., 89th Div. Age, thirty-one years. Date of admission, February 27, 1919. Date of injury, September 29, 1918. Date of operation, March 21, 1919.

Diagnosis—

Fracture, old, compound, comminuted, with loss of about 1 inch of bone in lower third, right ulna. Result of G. S. W. shrapnel, received in action on St. Mihiel Front, France, September 29, 1918.

Operation—

Resection of ends of fragments and removal of all fibrous tissue and callus, leaving a gap of about 2½ inches between fragments. Graft and inlay made with Albee saw. Graft of 2¾ inches taken from right tibia, and fastened in place with kangaroo tendon.

Operators—

Major Frank Martin, Lieutenant Hatch, Captain Peterson.

Remarks—

In this patient there was a gutter wound and the incision had to be made necessarily through the scar tissue. The scar tissue broke down and the incision has not entirely closed. The X-ray indicated that the graft is viable, but I am not entirely convinced that trouble may not appear later.

Result—

June 4, 1919. Callus formation in this case has occurred very satisfactorily, and the last X-ray picture, taken June 3, 1919, shows callus bridging entirely across from fragment to fragment. This is abundantly shown and the graft is almost completely absorbed. The outcome as to the restoration of his skeleton and complete function will be eminently satisfactory.

FIG. 28.—Case XII. Before operation.

FIG. 29.—Case XII. After operation.

Case XIII. Ulna.

J. C. M., Sgt., Co. D, 354th Inf. Age, twenty-eight years. Date of admission, January 27, 1919. Date of injury, September 24, 1918.

Diagnosis—

1. Old G. S. fracture, ulna, upper third right. 2. Old G. S. fracture, radius, upper third right. 3. Osteomyelitis ulna (with loss of one (1) inch of substance and malunion). Both fragments of ulna separated and firmly united in deformity by callus formation to radius, locking the two bones together and preventing both pronation and supination, following old G. S. fracture incurred in Argonne Woods by H. E. shell fragment September 24, 1918, both bones being shattered.

Condition on Admission—

Upon entrance the principal thing noted was a suppurating bone sinus at entrance of old G. S. fracture over upper third ulna right, with loss of supination.

Operated—

February 21, 1919, for osteomyelitis. Sinus dissected out and bone cavity thoroughly removed by chisels, gouges and curette. Wound packed widely open with Dakinized gauze and allowed to granulate.

Operator—

Major Frank Martin, assisted by Captain Stoner.

Operation—

For bone graft, May 3, 1919. Operation done to repair non-union in ulna, after the bridge of callus was chiseled from between lower fragment of ulna and radius and upper fragment of radius. The fibrous mass which was found between the fragments of the ulna was left and a graft was cut immediately over the ununited fragments well into the lower fragment and reversed, giving good bone to bridge the gap. This was fastened in place with kangaroo tendon. Wound closed and arm put in semiflexion and extreme supination in plaster cast.

Operator—

Major Frank Martin; Assistants, Captain Brothers, Lieutenant Hatch.

Remarks—

This patient's wound has healed, sutures were removed May 11, 1919. Considerable bloody oozing has occurred in this case, which, however, has ceased now.

Result—

June 3, 1919. Wound healed under one dressing, function of arm returning very satisfactorily. Firm, bony union has occurred and all seems well for an excellent result.

FIG. 30.—Case XII. After operation.

Case XIV. Femur.

V. V. J., Pvt., Co. G, 139th Inf. Age, twenty-two years. Date of admission, March 19, 1919. Date of injury, September 29, 1918. Date of operation, April 5, 1919.

Diagnosis—

Fracture, compound, femur left, in lower third, resulting in malunion with 3 inches shortening. Result of G. S. W., M. G. bullet, received in action in Argonne, France, September 29, 1918.

Operation—

Refracture of femur. Removal of excessive callus. Sliding inlay bone graft taken from upper fragment. Cast applied.

Operators—

Major Frank Martin, Major Dickson, Captain Kauffman, Lieutenant Hatch.

Remarks—

This proved to be a very difficult case. A glance at the X-ray picture and notation of the great shortening, with a firm, bony lateral union between fragments, will show what I mean. The chief difficulty was to overcome the shortening without shortening the thigh. When the bony union was chiseled apart and an effort made to deliver the fragments into the wound (which was an external aspect of thigh), there was excessive hemorrhage from the new blood supply which had formed at the site of the union. This however, was soon arrested when the fragments were unlocked and delivered, and by making firm extension it was found that the fragments could be brought practically end-to-end. The sharp points of the fragments were sawed off and a perfect end-to-end apposition was accomplished. Prior, however, to finally bringing them end-to-end, a sliding graft was cut from upper fragment and fastened in place, and when lower fragment was brought end-to-end, all that was necessary was to fix the lower end of the graft into the inlay below. Healed under one dressing and patient still in plaster case.

FIG. 31.—Case XIV. Before operation.

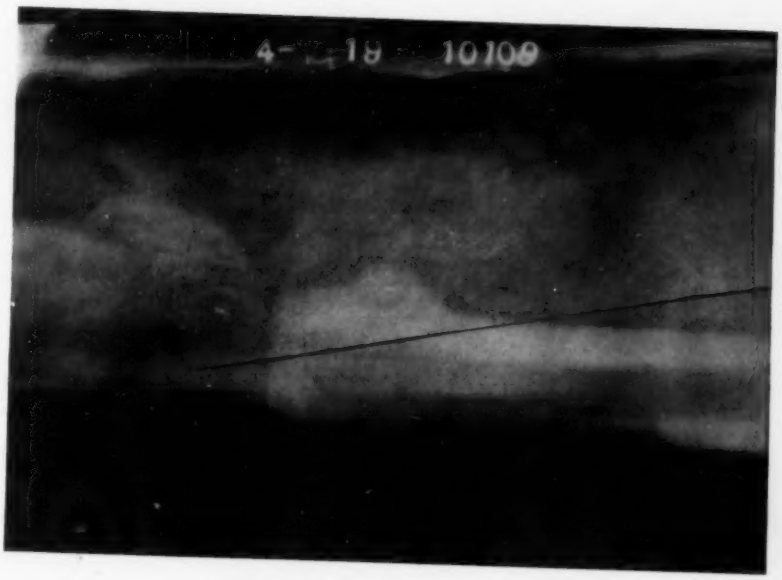

FIG. 32.—Case XIV. After operation.

Case XV. Tibia.

W. A. M., Pvt., Co. D, 65th C. A. C. Age, twenty-two years. Date of admission, January 27, 1919. Date of injury, August 28, 1918. Date of operation, January 28, 1919.

Diagnosis—

1. Fracture old, compound, comminuted, healed, tibia, lower third, right. Main line of fracture transverse, located 5 cm. above ankle-joint. Another transverse line of fracture is located 10 cm. above ankle. Two fragments lie between these lines of fracture, one being in good alignment and the other displaced backward and upward. 2. Fracture, old, ununited, compound, comminuted, healed, fibula, right. Line of fracture 11 cm. above ankle-joint. 1 and 2 accidentally incurred August 28, 1918, in motorcycle accident at Toul, France.

Operation—

Bone graft, sliding inlay, tibia, right. Cast applied.

Operators—

Major Frank Martin, Captain Whitlatch, Lieutenant Hatch.

Remarks—

In this case a long graft was cut from the upper to the lower fragment across the point of malunion and the graft reversed. As the alignment was good, the gap in the bones was bridged well by the reversed end of the graft, and union took place rapidly. It emphasized the importance of having the graft good and long, because, as is well known, the ends of these bone fragments for 1½ inches have practically lost their osteogenetic function, and unless the scaffold is long enough to get well into healthy bone, ultimate union will not take place.

Result—

Excellent, wound healed under one dressing, good bone union.

FIG. 33.—Case XV. Before operation.

FIG. 34.—Case XV. After operation.

Case XVI. Tibia.

L. A. T., Pvt., 476, M. T. C. Age, twenty-one years. Date of admission, March 5, 1919. Date of injury, January 9, 1919. Date of operation, March 7, 1919.

Diagnosis—

1. Fracture, compound, comminuted, ununited, middle third, tibia, left. 2. Fracture, old, compound, comminuted, partially united, upper third, fibula, left. 1 and 2 result of motorcycle accident near Doulingo, France, January 9, 1919.

Operation—

Open operation. Sliding graft 3½ inches from upper fragment tied in place with kangaroo tendon. Cast applied.

Operators—

Major Adams, Captain Brothers, Lieutenant Hatch.

Remarks—

Reversed graft and speedy recovery followed.

Result—

Firm bony union has taken place, with good function.

FIG. 35.—Case XVI. Before operation.

FIG. 36.—Case XVI. After operation.

Case XVII.

J. E. W., Pvt., Co. B, 15th F. A. Age, twenty-two years. Date of admission, February 7, 1919. Date of injury, October 6, 1918. Date of operation, February 12, 1919.

Diagnosis—

Old G. S. W. fracture, tibia, lower third, left, compound comminuted, ununited, with destruction of shaft for distance of 4 cm. Result of G. S. W. received in action on Champagne Front, France, October 6, 1918.

Operation—

Bone graft, sliding inlay taken from upper fragment, tibia.

Operators—

Major Frank Martin, Captain Brothers, Captain Witlatch.

Remarks—

Incision in this case necessarily had to be done through some old scar tissue, due to the fact that he had large gutter wound of soft parts at site of nonunion. The wound healed primarily, but at lower end the scar tissue broke down superficially, and although it did not infect the graft, there is still a small area still unhealed, size of thumb nail.

Result—

Firm union has been established and graft is well incorporated in callus.

FIG. 37.—Case XVII. Before operation.

FIG. 38.—Case XVII. After operation.

Case XVIII. Tibia.

L. R. T., Pvt., Motorcycle Co., Q. M. C. Age, twenty-three years. Date of admission, December 29, 1918. Date of injury, October 13, 1918. Date of operation, January 7, 1919.

Diagnosis—

Fracture, old, compound, ununited, tibia, middle third, left. Accidentally incurred October 15, 1918, in Paris, France, by striking a cab while riding a motorcycle.

Operation—

Old, ununited fracture, marked overriding, fibrous union. Correction of above with sliding bone graft taken from the upper fragment of left tibia, held in place by three kangaroo tendon sutures. Periosteum sutures over bone with No. 2 chromic gut. Plaster-of-Paris bandage applied from middle thigh to toes.

Operator—

Major Hobby, Captain Adams.

Result—

Wound healed primarily. Recovery uneventful. Good, firm, bony union of the limb has been restored.

FIG. 39.—Case XVIII. Before operation.

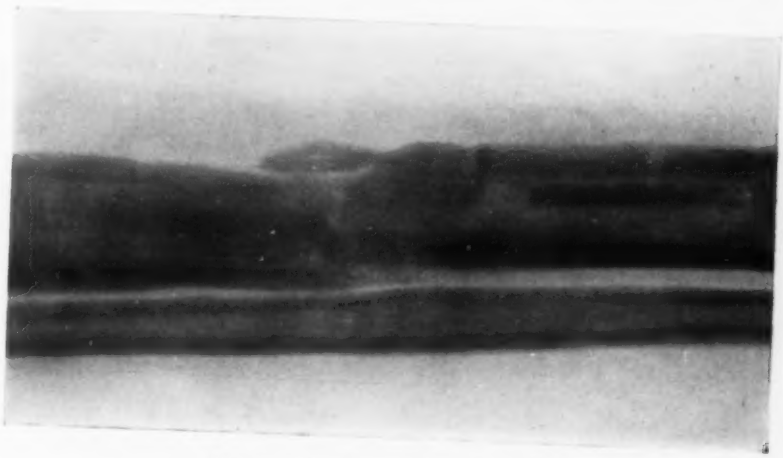

FIG. 40.—Case XVIII. After operation.

Case XIX. Tibia.

C. B. K., 2d Lt., Co. B, 59th Inf. Age, thirty-five years. Date of admission, January 17, 1919. Date of injury, September 29, 1918. Date of operation, January 23, 1919.

Diagnosis—

1. Old fracture, tibia, right (G. S. W.), junction of upper and middle third, with loss of 1½ inches of substance. 2. Osteomyelitis, with many suppurating bone sinuses. 1 and 2 incurred in action near Mt. Faucon, France, September 29, 1918, by M. G. bullet. Fibula intact and acting as splint for tibia.

Operation—

Sequestrectomy and the osteomyelitic ends of the fragments removed with Gigli saw and graft put in place in order to bridge across and scaffold this gap, hoping that, in view of the fact that the cavity had been so thoroughly cleaned, it would at least maintain separation of fragments even if it did not form bone. The object of keeping the fragments separated was accomplished and the large cavity filled in quite promptly, but the graft did not live but acted as scaffolding and bone formed around it. The graft was later removed, after being left in for many weeks.

Result—

The wound has practically closed and the ultimate result is undetermined as to whether another graft will be needed. It was considered almost certain that the graft would not be successful at time of operation, because the culture taken then showed non-hæmolytic streptococci.

Operators—

Major Frank Martin, Lieutenant Hatch, Lieutenant Buchbinder.

FIG. 41.—Case XIX. Before operation. This shows splint in which patient arrived from over-seas.

FIG. 42.—Case XIX. Before operation.

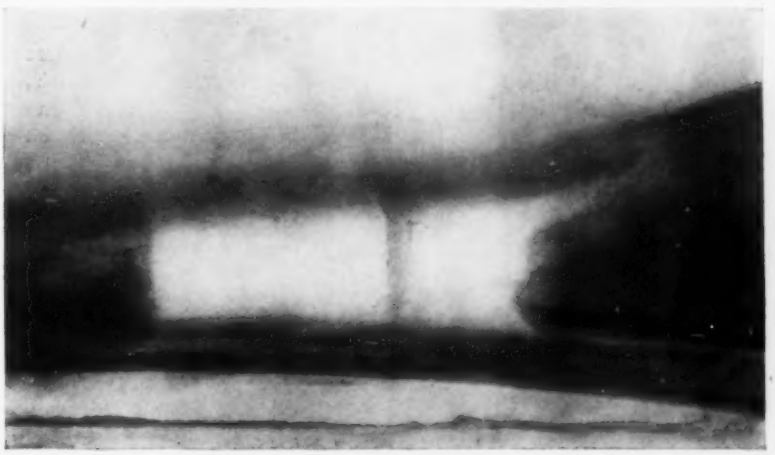

FIG. 43.—Case XIX. After operation.

Case XX. Resection of Tibia and Fibula for Osteomyelitis. (Fixation Wire Method.)

D. C. M., Pvt., Co. C, 168th Inf. Age, twenty-five years. Date of admission, April 28, 1919.

History—

Was injured October 15, 1918, in action in Argonne Forest, France, by gunshot wound (high-explosive fragment), left lower leg, lower third, with compound comminuted fracture, tibia and fibula, lower third, malunion and osteomyelitis.

Condition on Admission—

Patient was admitted as convalescent wound case on crutches, and was not ill otherwise.

Diagnosis of Ward Surgeon—

Osteomyelitis and fracture with malunion, tibia and fibula at middle and lower thirds.

X-ray Report—

Dated April 30, 1919. Old compound comminuted fracture of left tibia and fibula at junction of middle and lower thirds. A considerable degree of angulation backward and inward. Loss of tissue a distance of 1½ cm. between the ends of the fragments. Moderate amount of callus formation on posterior and outer side of tibia, with small amount between the ends of the fragments. The lower fragment of the fibula is displaced backward 1½ cm. Small amount of callus.

Operation—

Resection of tibia and fibula, left, at junction of lower and middle thirds. Fixation of bones with silver wire. Jones combination foot and ankle splint applied.

Operators—

Major Martin, Lieutenant Hatch, Lieutenant Reed.

Remarks—

In view of the infection and osteomyelitis, both wounds were left open (the tibia resection was done by incision over tibia, and the fibula resected by external incision over fibula) and packed with Dakin gauze. The wires will be removed as soon as fixation becomes established.

Result—

It is too soon to report as to the results.

FIG. 44.—Case XX. Before operation.

FIG. 45.—Case XX. Before operation.

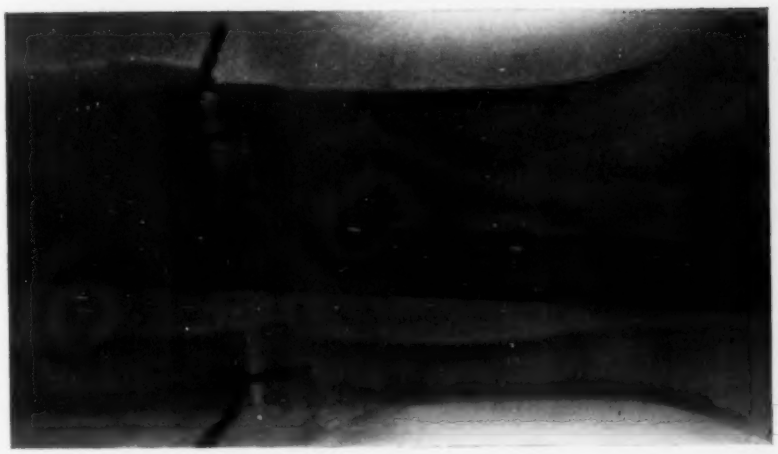

FIG. 46.—Case XX. After operation.

Case XXI. Open Operation for Resection and Fixation of Fracture, First Metacarpal.

S. O. S., 1st Lt., Co. L, 140th Inf. Age, thirty-two years. Admitted, January 13, 1919. Injured, September 29, 1918.

Admission Diagnosis—

1. G. S. W., soft parts, penetrating popliteal space, right, dividing popliteal artery (as evidenced by no pulsation in either anterior or posterior tibial artery).
2. G. S. W. of thigh, penetrating middle third posterior right.
3. G. S. W., left thumb, with fracture of first metacarpal, fragments united in overriding deformity, at seat of which X-ray shows a large metallic fragment of H. E. shell, imbedded in the callus. This is well classed as a contact fracture.
4. G. S. W. left elbow posterior.
5. G. S. W. right shoulder, posterior aspect.

1, 2, 3, 4 and 5 incurred while in action at Argonne Forest, France, by high-explosive shell fragments and rifle bullet on September 29, 1918.

This patient had an acute severe hemorrhage in pre-operative ward from wound in right popliteal artery so urgent in character that tourniquet was applied and blood transfusion resorted to. Upon entrance to the mobile hospital No. 2 the wound of entrance in popliteal space was enlarged and popliteal artery ligated above and below, in consequence of the great shock incident to hemorrhage other wounds not opened. On October 2, 1918, he was transferred to Base Hospital No. 28, and again transferred to Base No. 6 on October 11, 1918, where splint was applied to right leg and wound closed; while there, developed epidemic influenza. Arrived at Staten Island, December 11, 1918.

Upon arriving at this hospital (Base, Fort Riley, Kansas), the chief conditions noted on admission were pain in right thigh and leg, with impaired function, in that patient was unable to completely extend leg on thigh and marked impairment and loss of function in left thumb incident to the deformity at site of fracture in the first metacarpal bone, where as above noted there was an overriding of fragments with a large metallic fragment consisting of a portion of high-explosive shell, which was firmly embedded in callus at seat of fracture.

The chief condition calling for treatment when he arrived at this hospital was, first, to overcome the impaired function in his left limb, active and passive massage, which proved most effectual, and, secondly, to overcome the deformity incident to the overriding fragments in the fractured first metacarpal bone, and incidentally to remove the foreign body (H. E. shell fragment). This was done and complete restoration of function resulted therefrom.

He was discharged May 20, 1919, to duty, with a perfect functioning hand.

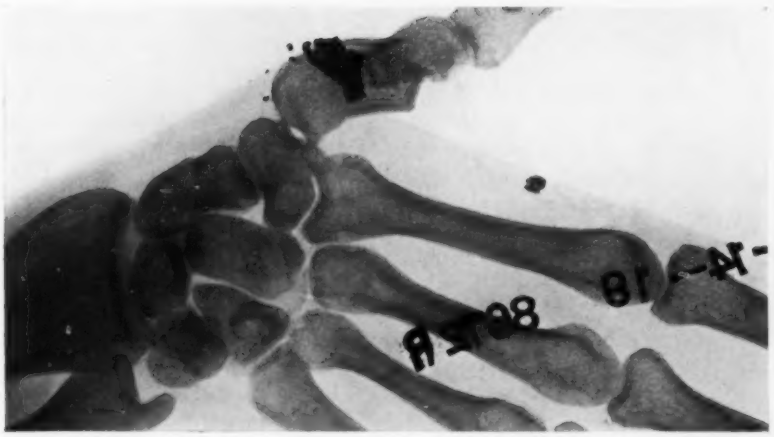

FIG. 47.—Case XXI. Before operation.

FIG. 48.—Case XXI. After operation.

Date of Operation—

January 16, 1919.

Operation—

(Correction of deformity with fixation of fragments in corrected position with kangaroo tendon and removal of fragment.)

Long incision (4 to 5 inches) made over the dorsal surface of first metacarpal bone, site of fracture uncovered, periosteum incised for a distance of 2 to 3 inches, stripped back with periosteal elevator, thereby entirely uncovering the mal-united fracture, fragments were unlocked by means of Lane holding forceps and with chisel. Metallic fragment which was found incorporated in callus removed, fragments delivered into wound and brought end-to-end and fixed in this corrected position by kangaroo tendon. Wound closed without drainage, layer by layer. Sterile dressings applied and an external splint consisting of a narrow strip of board put on to support and maintain fragments in good condition.

Post-operative Care—

This patient needed very little further surgical attention, dressings were not changed for ten days (as he ran a perfect aseptic course), when wound was then found entirely healed under one dressing. Sutures removed and external splint reapplied and continued in use for four or five weeks. Following this he had massage and daily physiotherapeutic treatment by an efficient reconstruction aid.

Operator—

Major Frank Martin, M. C. Assistant, Lieutenant Floyd F. Hatch, M. C.

Result—

The surgical result in this case was eminently satisfactory. Patient returned to duty May 20, 1919. The reason of his long stay in the hospital was in consequence of other conditions needing surgical care; for instance, on April 11, 1919, a foreign body consisting of a large fragment of H. E. shell which was embedded in his left shoulder excited suppuration in the soft parts and necessitated removal under a local anæsthetic on the above mentioned date. Further, the need of care and treatment to overcome the impaired function due to the G. S. W. in popliteal space and the division of his popliteal artery and injury of peroneal nerve, which condition is shown by the neurological report herewith incorporated.

Neurological Report—

There has been an incomplete anatomic division of the peroneal nerve with an initial paralysis and foot-drop; this has been almost completely recovered from; there is a little weakness in extension remaining. There is pain in the knee at times, most probably as result of inclusion of nerve in scar. There is practically complete protopathic recovery.

There is absence of pulsation in the dorsalis pedis, due to ligation of the popliteal artery; this is expressed in the clinical symptoms of intermittent claudication, pain and spasm of the calf muscles after walking a short distance and at times coldness of extremity. Recommend reëducational work at the gymnasium, active and passive massage.

THE CORRECTION OF DEFORMITY IN FRACTURES, WITH A NEW CONCEPTION OF THE MECHANISM OF FRACTURES OF THE UPPER EXTREMITY *

By T. Turner Thomas, M.D.
of Philadelphia

Few subjects are older than fractures and few are newer in the sense of the interest manifested by the profession at the present time. The problems of abdominal surgery, although of very recent development, have been much better solved. The revelations of the X-ray have been largely responsible for the interest transferred to fractures. It has greatly disturbed our peace of mind and has stimulated discussion concerning the effectiveness of long accepted methods of treatment. The operative treatment was practically unknown before 1895, when the X-ray was discovered, and operation was avoided as far as possible even in ununited fractures. It is rarely avoided now in the latter group and is rapidly gaining favor in the former, although the total number of cases operated on is still relatively very small.

It is the great question in fractures still up for settlement. Lane advised operation in nearly all fractures and has attracted many followers, but the vast majority of surgeons and general practitioners are less enthusiastic and are still looking for more light before taking a decided stand on the question. We are being urged, and very properly, to employ the X-ray, not only for diagnosis but also to ascertain the results of our efforts at the reduction of deformity. The probability is that the price of the first X-ray is a great discourager of more with many people, physicians as well as patients, so that the physician often must content himself with his skill in palpation when determining his success at reduction. It is a poor guide but he finds encouragement in the long-continued teaching still found in some of our authoritative text-books and systems that " the reduction of fractures is usually simple and satisfactory." Good union and good function usually result which give him satisfactory proof of a proper reduction.

According to my observation, nothing stimulates the operative treatment of fractures more than the taking of an X-ray after each attempt at the reduction of deformity. It furnishes the surgeon inclined to operation with a compelling argument. We have been very slow in learning that the non-operative reduction of fracture deformity is not " usually simple and satisfactory," but in the shafts of the long bones with considerable overlapping is practically impossible. An acid test on this question would be to search the literature for reports of such fractures (of the femur, humerus, both bones of the leg or forearm) with skiagraphs taken before and after the reduction. If reduction is easy it should not be difficult to find plenty of such case reports. If it is difficult or impossible to find any, it should be good evi-

* Read before the Lackawanna County Medical Society, Scranton, Pa., April 29, 1919.

dence that such reduction of deformity is difficult or impossible. I have not yet found any. I have had special interest in this subject for a few years but my success has been small. This does not apply, however, to fractures of the ends of the long bones, as the Colles', surgical neck of the humerus and ankle where complete overlapping is not the rule. There seems to be a tendency to regard reduction in transverse fractures as more satisfactory than in oblique fractures. I have not found it so, and I have been gradually forced to the conclusion that as a rule in fractures of the long bones with overlapping we must be contented with union with overlapping or operate to correct the deformity.

The explanation of the trouble seems simple enough. It is difficult to understand why anything else should be expected. The chief function of muscle is to contract on the slightest irritation. As soon as fracture with overlapping occurs the irritation of the fragments causes contraction and shortening of the surrounding muscles. Before reduction can be accomplished and maintained these muscles must relax and lengthen to the normal, or enough extension must be applied to stretch them to the normal length, and this must be continuously maintained. Neither the Buck's extension, Steinmann's nails, nor any other method of extension yet devised has been proved by X-ray to accomplish this satisfactorily. I have been experimenting with a method, applying particularly to fractures of the leg, the principle of which is very old. The knee and foot are encased in plaster casts, traction is made on the foot and counter-traction at the knee. I have no trouble in applying and maintaining all the traction I please. But the dorsal surfaces of the foot and heel will not tolerate enough traction to overcome sufficiently the contraction of the muscles about the fracture. Immediately after the fracture we have only the muscle contraction to contend with. Within a few hours the muscles become infiltrated with blood and exudate and actually shortened. With organization of the exudate they become permanently shortened.

It is of primary importance, therefore, to apply extension very early. Of greater importance is the fact that we know practically nothing about how the deformity is produced. We have long known that the most common fractures of the extremities have typical deformities and this is particularly true of the upper extremity. I have yet to observe in fracture of the middle of the clavicle with overlapping anything but a downward and inward displacement of the outer fragment (see Fig. 1). The same uniformity of displacement is largely found in the other common fractures of the upper extremity. There has never been but one plausible explanation for this very interesting and important fact, muscle pull, *i.e.*, in each instance one or more certain special muscles pull the fragments into the typical position. I have taught this for many years but have been losing confidence in it for several years and now have none. There is another view, probably long existent but never insistent, and having very few open supporters, or at any rate few strong supporters, the view that the deformity is due to the frac-

turing force. The muscle pull view has one great advantage over it, it is readily seen to be a constant force and to produce a constant deformity requires a force acting always in the same direction. Our present view seems to be that the fracturing force may be due to direct or indirect violence and that in either case it may be applied from any direction.

There is one fracture in the upper extremity, and only one, which is almost if not universally admitted to be due practically always to the same

FIG. 1.—Typical deformity in common fracture of clavicle with overlapping. Almost never varies. Inner fragment up, outer down and in.

force, the fall on the hand. This is the Colles' fracture. An exception is a fracture in the same situation from "back-firing" while cranking an automobile, but the force here is essentially the same as in a fall on the hand. Muscle pull is probably no longer invoked to account for this typical deformity. In my judgment, the proof of the cause of the deformity is in the deformity itself. Every feature of it is easily explainable by the force of a fall on the palm of the hand and nothing else can explain it. I have long been convinced that all the common and typical fractures and dislocations of

the upper extremity are due to the same cause (that in falls the patient practically never strikes first on the elbow or shoulder), and I have been trying to put together in plausible if not convincing form the observations and reasons which have led me to this conclusion. It cannot be positively demonstrated, because at the moment of the fall no patient can deliberately observe and afterward describe accurately the kind of force which caused the fracture. It is a moment of extreme excitement and everything makes for a disordered mind. The patient frequently states that he struck on his elbow or shoulder, probably because in trying to explain afterward how it happened he assumes that he struck where he has most pain. Where, then,

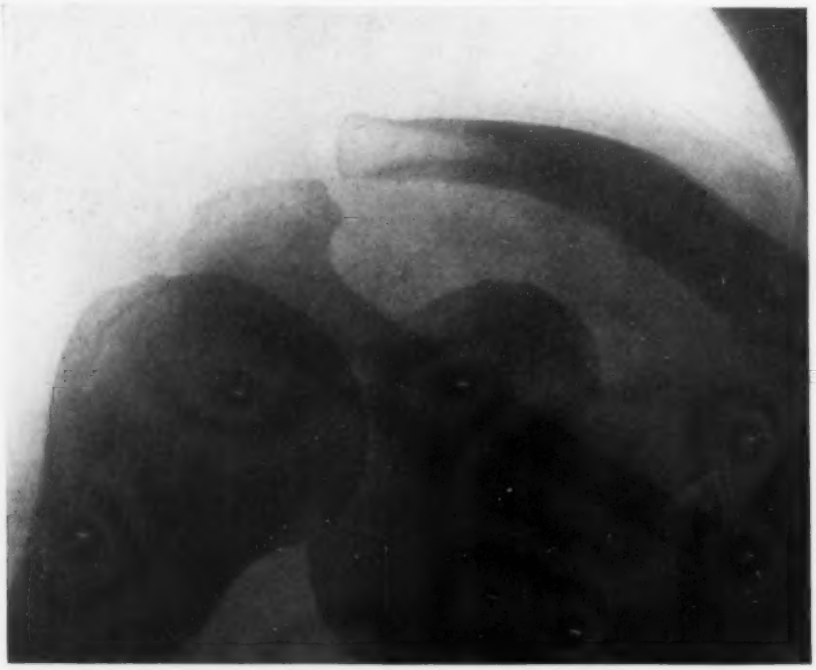

FIG. 2. — This dislocation at acromioclavicular joint practically constant. Essentially same deformity as in fig. 1, except for absence of overlapping, which is prevented by untorn powerful coracoclavicular ligaments.

may we look for light if not to the patient? I believe that in the deformity of all these typical and common fractures we have an almost untapped wealth of information.

In considering the effect of an indirect force upon it, it is my rule to look upon the skeleton not as a collection of separate pieces of bone, but as one continuous piece, the bones being bound together by powerful ligaments into a strong frame-work constructed for the resistance of force. The ligaments are probably as strong as the bones, generally speaking, because they must resist the same forces and because dislocations are less frequent than the corresponding fractures with displacement of the fragments. An indirect

force, as a fall on the hand, puts the strain on the skeleton of the upper extremity as a whole and if great enough will break it at its weakest point. The break may occur through a bone, with or without displacement, according to the degree of force applied, or through a joint with or without displacement. A break of the skeleton through a joint with displacement of the fragments would be a dislocation, without displacement it would be a sprain, or merely a tearing of the ligaments. After reduction of a dislocation, the remaining lesion would be the same except as to degree, *i.e.*, torn ligaments. Thus many dislocations with immediate spontaneous reduction

FIG. 3.—Common subcoracoid or anterior dislocation of shoulder joint. Raise humerus to same plane as clavicle and we shall have same deformity as in figs. 1 and 2. The inner fragment will be up and the outer down and in.

pass for sprains. The important point here is that the same force may produce a fracture or dislocation depending upon whether the skeleton gives way through a bone or joint and the deformity in either case will be the same because the breaking force is the same.

What excuse can we have for assuming that most fractures and dislocations of the upper extremity are due to the fall on the hand? Fractures and dislocations are common only in man and are by far most common in the extremities, especially in the upper. The lower animals are quadrupeds. Consequently, they very rarely lose their balance and fall, and when they do the skeleton does not break, in most animals, because the weight of the

body and the height of the fall are so slight. Most fractures that they do suffer are probably from direct blows. But the fall is the great accident in man and is the price he pays for the tremendous advantage of balancing himself on his two small plantar surfaces in the upright position and developing his upper extremities for more highly special work. His falling career starts when he begins to give up crawling on his four extremities in order to learn to walk on two. At first he does little else but fall. With increase in

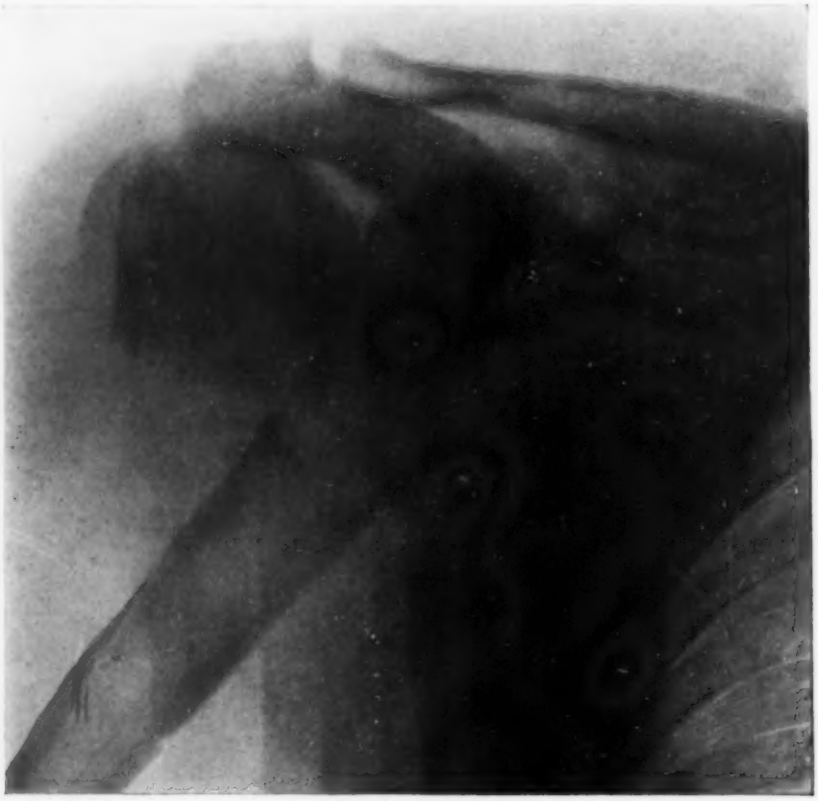

FIG. 4.—An extreme but typical deformity in fracture of surgical neck of humerus. Identically same displacement as in fig. 3. Same angulation and subcoracoid position of lower fragment as in the dislocation. When humerus is raised to same plane as clavicle, deformity will be same as in figs. 1 and 2.

skill he assumes more risk and never succeeds in maintaining his balance under all circumstances.

Through the centuries the instinct of self-preservation never fails to operate so that in falling we have become so practiced in doing the safest thing that we reflexly and unconsciously sacrifice the less important to save the more important and vital parts. If we made no defensive effort in falling we would strike much more frequently on the head or trunk or both. But the skull contains the brain, the most delicate and vital structure in the body, and fractures of the skull for this reason are very frequently fatal. The

chest contains the heart and lungs which are also vital organs, and a severe fall on the thorax would likewise threaten life from its crushing impact. But the common serious result of a fall on the extremities is a fracture or dislocation, which very rarely threatens life. Therefore, instinctively and unconsciously we have come to sacrifice the extremities to save the head and trunk. Hence, fractures and dislocations are very much more common in the extremities. When we are losing our balance and are about to fall we first make every effort to restore our equilibrium on our feet and, failing in

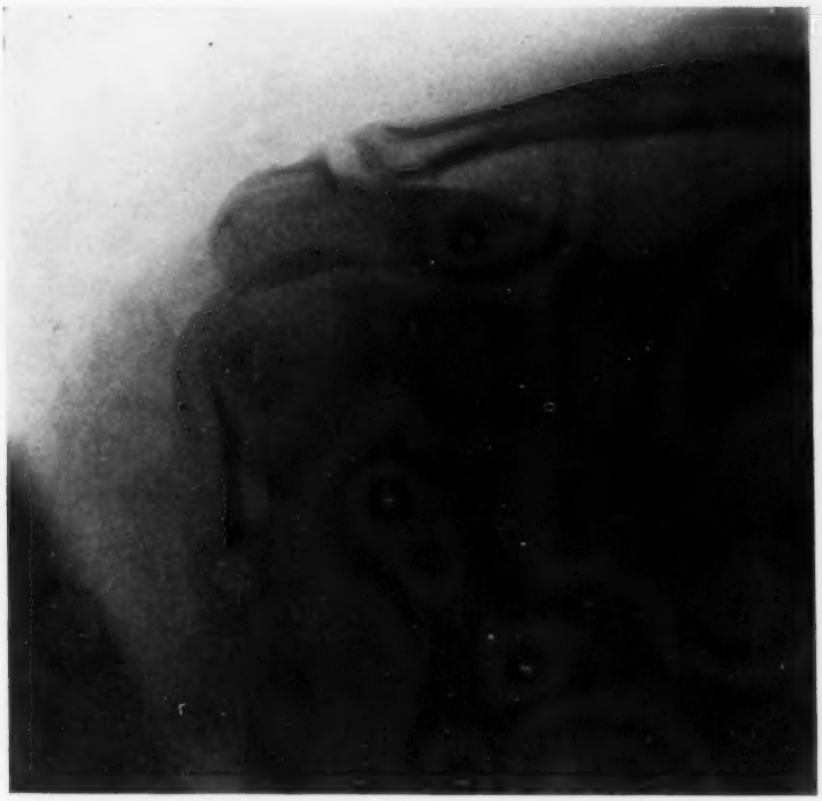

FIG. 5.—Same case as fig. 4, after reduction.

this effort, the whole body (in an adult weighing from about 100 to 250 pounds) suddenly is without any contact with the ground and a variable distance from it. The momentum with which it strikes the ground will depend upon the weight of the body, the height of the fall and the initial force of the fall. For example, if a person is running rapidly when he loses his balance the momentum will be greater than if he falls from a standing or walking position, as when he slips on a banana peel or the ice.

Just as we learn from practice to do the right thing automatically and unconsciously at a moment's notice, while running an automobile, in an emer-

gency, so we have learned to do much more automatically the right thing in a fall. The upper extremity is interposed rigidly straight at the elbow with palm down to break if it must. It is a life-saving procedure. This explains the greater frequency of fractures and dislocations of the upper extremity. It must receive the whole weight of the body driving toward the ground.

FIG. 6.—A typical displacement of both fragments in fracture of surgical neck of humerus. Fractured surface of upper fragment turned upward and outward suggesting that it remained fixed in abduction, in which position fracture occurred, the lower fragment ascending as it fell to side by gravity. This arrangement of both fragments is not uncommon in fracture dislocation.

The same kind of force in milder degree can be exerted on the upper extremity if we disarticulate the upper extremity of a cadaver at the shoulder joint, place the palm on the ground, hold the elbow rigidly straight and hammer on the head of the humerus with a mallet. By this experiment I have produced typical fractures of the head of the radius and a few Colles'[1]

[1] University of Pennsylvania Medical Bulletin, Sept. and Oct., 1905.

fractures. My work was done fifteen years ago and was reported in 1905. Von Bruns had produced fractures of the radial head in this way twenty years before. An observation made at that time has an important bearing on the theory that posterior dislocations of the elbow are due to hyperextension. Every blow of the mallet on the head of the humerus, without exception, produced flexion of the elbow, the force of the flexion varying with the force

FIG. 7.—Same case as fig. 6, after reduction.

of the blow on the top of the humerus. Therefore, hyperextension cannot occur from a fall on the hand as has been maintained. It is likely that in every heavy fall on the hand the elbow flexes and the patient strikes secondarily on the elbow, which may explain the frequency with which patients say they struck first on the elbow. This flexion probably has much to do with the posterior dislocation of the elbow and the posterior displacement of the

lower fragment in a supracondyloid fracture of the humerus, to which reference will be made later.

We have already suggested that fracture-deformity, especially in the upper extremity, may be studied to advantage in connection with the mechan-

FIG. 8.—Fracture of shaft of humerus probably between insertions, above, of pectoralis major, teres major and latissimus dorsi, and, below, of the deltoid, with same deformity as is typical of fracture of surgical neck. According to muscle pull theory, upper fragment should be in and lower out.

ism of the fracture involved. We probably never have fully appreciated the significance of the fact that practically every common fracture and dislocation of the upper extremity has one typical deformity and only one. This includes fractures of the middle of the clavicle, dislocation of the outer end of the clavicle, and of the shoulder joint, fracture of the surgical neck

of the humerus and just above the condyles, posterior dislocation of both bones at the elbow and Colles' fracture. I have purposely omitted reference to fractures of the shafts of the humerus and forearm bones because I have no confidence in the supposed typical deformities in them (Figs. 8 and 9). They are said to be due to the pull of special muscles, a theory elaborated

FIG. 9.—Same case as fig. 8, after reduction. Reduction of such overlapping in fractures of shafts of long bones has been almost impossible to the writer, the result in this case being regarded as particularly good.

for many fractures long before the discovery of the X-ray, which does not corroborate it according to my observation. In the above group, however, there is no question concerning the character of the deformity nor the uniformity with which it occurs, in some the uniformity is more marked than in others. We are dealing now only with the cause of these deformities and the part each plays in showing the nature of the force producing it.

There is no occasion to argue here that the Colles' fracture is caused by the fall on the hand. I shall assume, too, that the typical backward and upward displacement of the lower fragment proves that this was the fracturing force. I have frequently seen and heard it stated and have never known it to be denied, that the common anterior dislocation of the shoulder is due to hyperabduction, the humeral head being pried out of the socket after

FIG. 10.—Supracondyloid fracture of humerus. Anteroposterior view before reduction.

the surgical neck comes against the outer edge of the acromion. Hyperabduction at the shoulder in the cadaver always produces an anterior dislocation, never a posterior, and this agrees with our experience in the living, in whom we almost never see posterior dislocations. In the ordinary fall hyperabduction occurs when the angle of the limb with the ground at the moment of impact is such that it is carried away from the body violently by

the force. It may occur also in grasping an object for support to prevent the fall. When the fall takes place the degree of force applied and the strength of the skeleton determine if it will break at some point. The degree of force applied determines the degree of the deformity, which is

FIG. 11.—Anteroposterior view of Fig. 10 after reduction. For explanation of indefiniteness of skiagraph see angle of elbow in fig. 13.

dependent upon the amount of force still unspent after the bone breaks. Children fall with less force than adults and consequently generally have less deformity. The angle of the limb with the ground at the moment of impact probably has much to do with the site at which it breaks. When

the limb is carried violently into abduction the whole skeleton in this region takes up the strain and is most likely to break at one of four places, middle of the clavicle, acromioclavicular or shoulder joint, or surgical neck of the humerus. In children it very commonly breaks in the clavicle and very rarely at the shoulder joint. In adults very frequently at the shoulder joint and less frequently in the clavicle. This indicates merely a relative variation in strength in these two portions of the skeleton at these different periods in life. Other

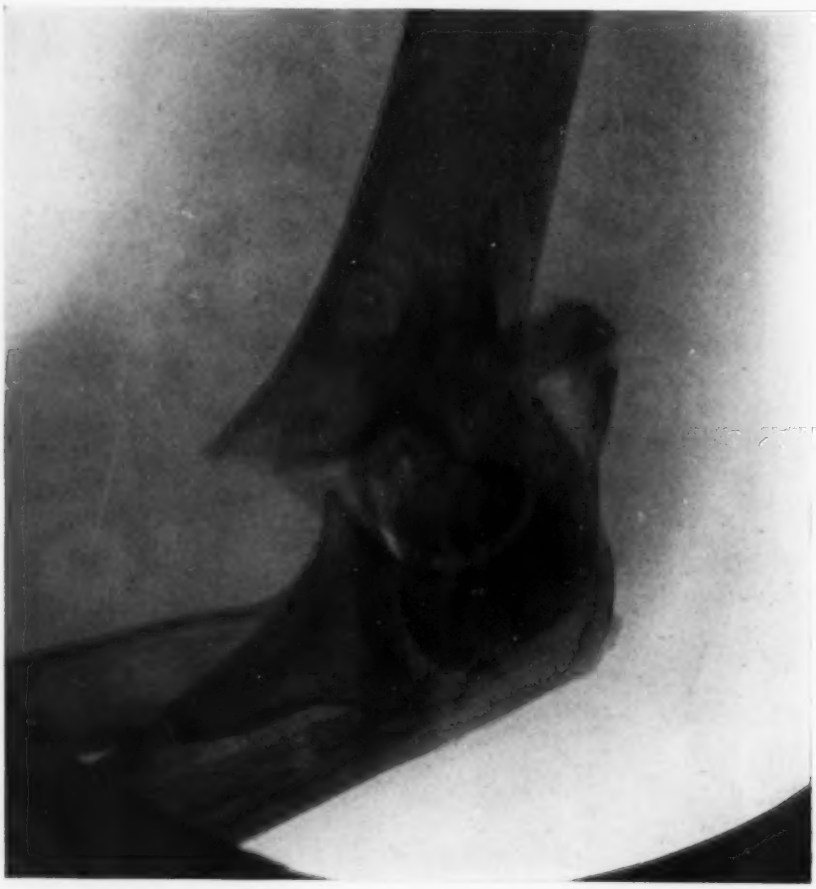

FIG. 12.—Lateral view of Fig. 10 before reduction.

similar variations have been noted. But in whichever site it gives way the deformity will be the same, proving that the breaking force is the same in all. If we imagine the humerus carried up to the same plane as the clavicle so that we may compare the deformities more easily, we shall find that when the deformity is marked enough to show it, the outer fragment in each instance is displaced downward, inward and forward; the inner fragment is always upward (see Figs. 1, 2, 3 and 4). In the upward dislocation of the

outer end of the clavicle, the outer fragment, the acromion, does not come inward much (see Fig. 2), because prevented by the powerful untorn coraco-clavicular ligaments. There is some variation in the deformity in fracture of the surgical neck of the humerus, perhaps because at the moment when the fracturing force is producing the typical deformity the arm is in abduc-

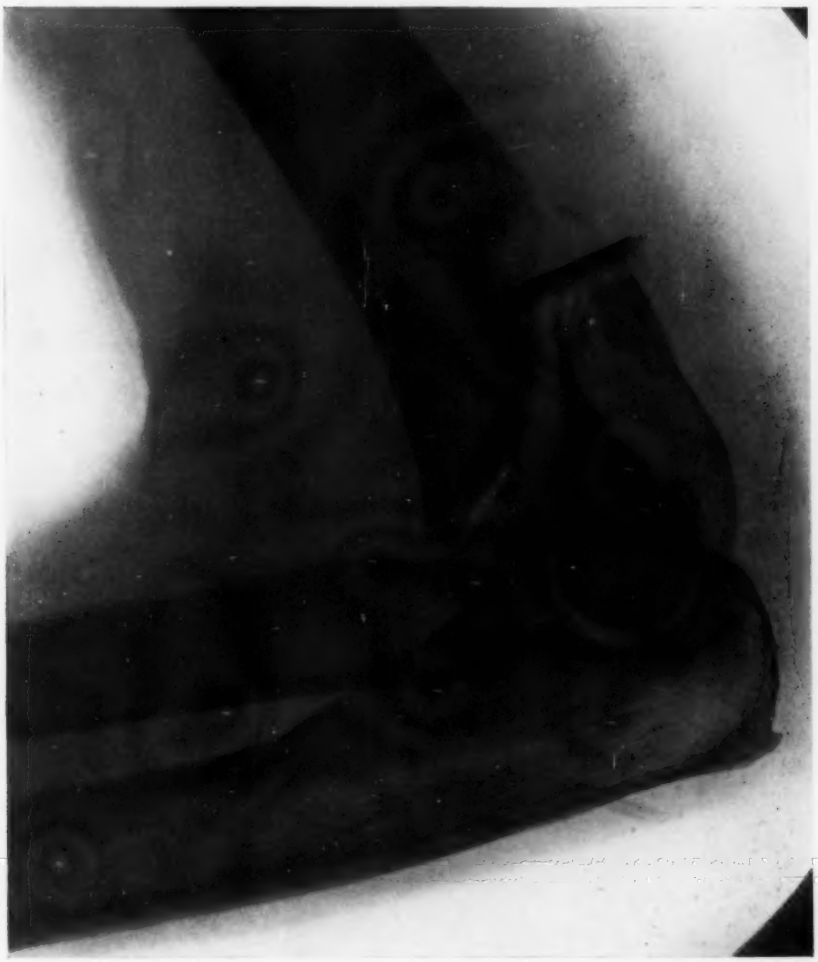

FIG. 13.—Lateral view of fig. 10 after reduction.

tion and when it falls from gravity it may change the position of the fragments. The essential fact remains, that the deformity is practically always the same in the common fractures and dislocations in this region, indicating that the fracturing force is practically always the same. But we agree that the fracturing force in the dislocation of the shoulder is hyperabduction. Therefore, we may assume that it is responsible for the other three breaks

of the skeleton in this region, and that the great underlying cause is the fall on the hand.

At the elbow the most common and typical breaks in the skeleton with displacement of the fragments are the posterior dislocation of both bones

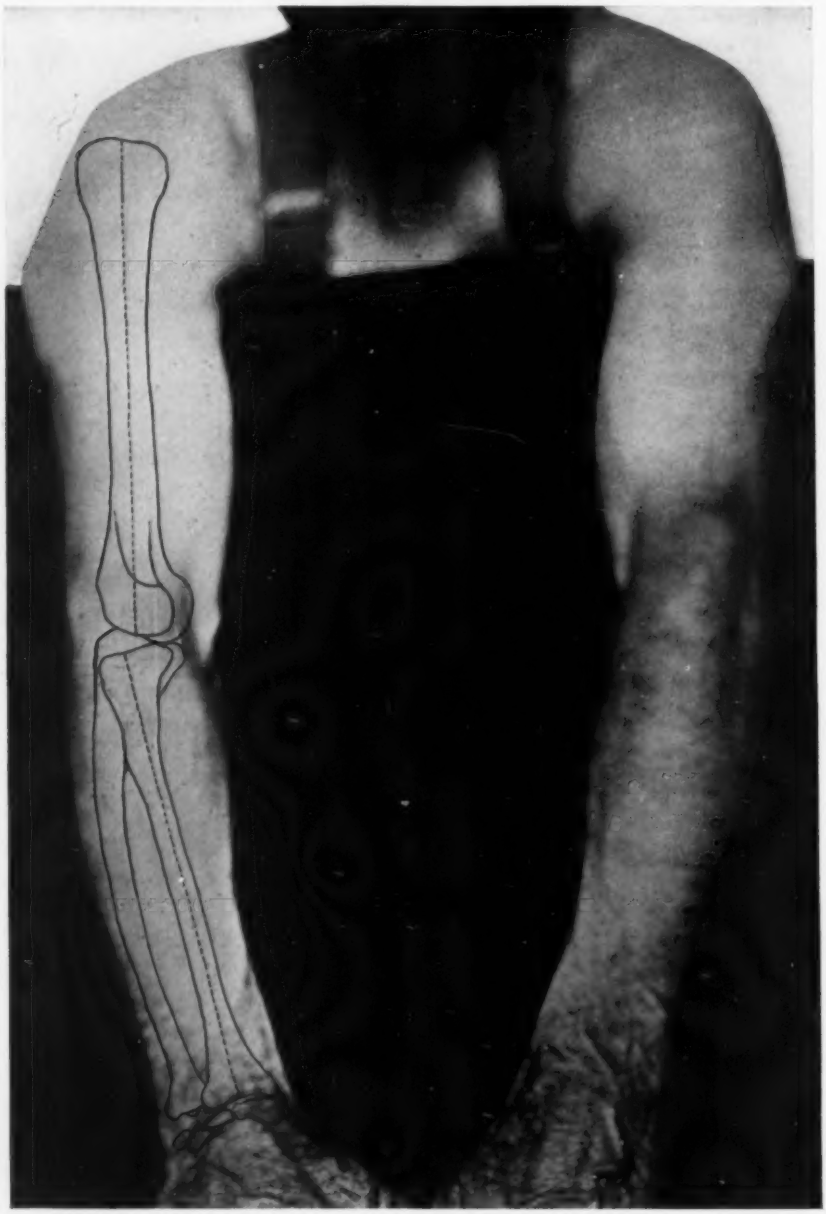

FIG. 14.—The upward thrust effect of a fall on the hand is exerted in the forearm, chiefly through the radius, because it practically alone articulates with the hand. When the skeleton breaks at or just above the elbow-joint the force, as shown here, drives the lower fragment upward and backward behind the upper fragment. (See Fig. 12, and any skiagraph of posterior dislocation of elbow.)

of the forearm and the supracondyloid fracture of the humerus. But we see at once that the deformity in both is essentially identical and what is much more important they are both identical with the deformity in the Colles's fracture which is admitted by everybody to be due to the fall on the hand. In all three the lower fragment is displaced upward and backward, and if this proves the causal influence of the fall on the hand for the Colles' why

FIG. 15.—The flexion of the elbow which, probably, immediately follows the first impact of the hand on the ground increases the tendency to thrust the lower fragment upward and backward.

not for the other two? In a fall on the hand the force of the falling body is transmitted downward through the upper extremity to the ground, *i.e.*, the line of force would pass through the extremity from above downward. The line of resistance, on the other hand, would pass upward from the hand to the trunk. When the skeleton breaks through the radius just above the wrist (Colles' fracture) the effect of the ground resistance is to thrust the hand with the lower fragment upward and backward into the typical posi-

tion. When from the same cause the skeleton breaks at the elbow joint or just above the condyles of the humerus, the effect of the ground resistance (Figs. 14 and 15) is to thrust the lower fragment in either case upward and backward because the line of resistance passes out of the axis of the arm in that direction. Any flexion of the elbow, which is probably the inevitable result of every very forcible fall on the hand, will increase the tendency to thrust the lower fragment upward and backward. We thus see that the common and typical displacements of these conditions are best explained by the fracturing force of a fall on the hand. The fact that in the dislocation as well as the fracture, the lower fragment may be displaced inward or outward as well as backward may be explained by a preponderance of force transmitted through the radius or ulna. It is well known that in rare cases the greater force may pass through to the ulna. It would be impossible to trace the exact mechanism but this is not essential.

Allis worked a long time to determine the mechanism of dislocations of the hip-joint, but after he had done this he gave us the best method of reduction we have. He first determined the path by which the head left the socket and then dragged it back through the same path in the reverse direction. If we know the mechanism of the common and typical fractures and dislocations of the upper extremity, it becomes obvious that we know how to apply the force that will best pull the displaced fragments into their normal position, *i.e.*, we would reverse the fracturing force and drag the fragments back into place. For several years I have been basing my efforts at correction of deformity and treatment of these fractures on the mechanism resulting from the fall on the hand, and have applied my knowledge of the mechanism to the best effect thus far in the treatment of injuries to the shoulder joint. I am here offering a few selected skiagraphs to show results of attempts at reduction obtained in some fractures.

CONCLUSIONS

1. The X-ray is not being used with sufficient frequency to determine the results of our efforts at reduction of fracture-deformity.

2. Sufficient use of it for this purpose would probably demonstrate that reduction of overlapping of fragments in fractures of the shafts of long bones, without operation, is rarely accomplished. The contraction of the surrounding muscles caused by the irritation of the fragments never relaxes until the muscle is permanently shortened by organization of the traumatic exudate which always infiltrates these muscles about the fracture. Probably no known method of extension can effectively overcome this contraction.

3. Most fractures and dislocations of the upper extremity are probably due to falls on the hand. A dislocation is merely a fracture of the skeleton at a joint with displacement of the fragments.

4. In a fall the upper extremity is interposed, palm down and elbow rigidly extended, to break the force of the fall, so that the mechanism by which the force is applied to it is essentially the same in all falls.

5. The common and typical displacements in fractures and dislocations of the upper extremity can be more effectively explained by such a fracturing force than by the theory of the pull of certain special muscles. Thus the upward and backward displacement of the lower fragment in a Colles fracture, now universally admitted to be due to a fall on the hand, is essentially the same as that found in the common posterior dislocation of the elbow and supracondyloid fracture of the humerus. There is as much evidence for ascribing these to falls on the hands as the Colles' fracture.

6. The typical displacement in fracture of the surgical neck of the humerus, dislocations of the shoulder and acromioclavicular joints, and fracture of the clavicle (when the humerus is placed in the same plane as the clavicle), is a downward, inward and forward displacement of the outer fragment and an upward displacement of the inner fragment. If hyperabduction at the shoulder is admitted to be the cause of the shoulder dislocation, why should it not be held responsible for the other three breaks in the skeleton in this region? The hyperabduction is due most frequently to falls on the hand, so that here as elsewhere in the upper extremity the great underlying cause of fractures and dislocation is the fall on the hand.

PNEUMOPERITONEUM

A METHOD OF DETECTING INTESTINAL PERFORATION—AN AID IN ABDOMINAL DIAGNOSIS

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(From the Department of Surgery, The Johns Hopkins Hospital and University)

The importance of an early diagnosis of a perforation of the intestinal tract, the difficulties in arriving at a correct diagnosis, and oftentimes, because of the limitation of our clinical methods, the uncertainty as to whether or not a perforation is present, are well recognzied. The purpose of this communication is to present an additional method by which a diagnosis of perforation of the alimentary canal can be made. So far as I am aware, this method has never been described. It is simple and should clear up many cases of doubt. I refer to the X-ray picture resulting when free air or gas is present in the peritoneal cavity—pneumoperitoneum.

In a paper on ventriculography which appeared in the Annals of Surgery, July, 1918, I made reference to the fact that intestinal perforation could be diagnosed by the X-ray. The statement was made solely upon the findings in a case which forms the basis for this communication. It was this X-ray which so strikingly revealed the value of air in röntgenography and was largely instrumental in suggesting the injection of air into the cerebral ventricles—pneumoventriculography.[1]

As a representative of Professor Halsted's staff, I was asked to see in consultation a case of suspected intestinal perforation in the medical service of the Johns Hopkins Hospital. The case had been carefully observed for two weeks by Dr. A. L. Bloomfield and the late Professor Theodore Janeway and other members of the medical staff. The diagnosis remained uncertain, but finally with the appearance of numerous intestinal hemorrhages, typhoid fever was looked upon as the most probable condition, despite persistent negative blood cultures and Widal tests. There had been no abdominal complaint, and no abdominal signs developed until the advent of the intestinal hemorrhages. Slight abdominal pain, general tenderness and distention then appeared and changed but little during the succeeding four or five days. Acute miliary tuberculosis with intestinal involvement was still regarded as a possibility, and with this in mind an X-ray of the chest was taken. I saw the patient January 3, 1917. For twenty-four hours there had been a gradual increase

[1] Dandy, W. E.: "Ventriculography Following the Injection of Air into the Cerebral Ventricles." Annals of Surgery, July 1918. "Fluoroscopy of the Cerebral Ventricles." Bulletin of the Johns Hopkins Hospital, February, 1919. "Röntgenography of the Brain after the Injection of Air into the Spinal Canal." (To appear in an early issue of the Annals of Surgery.)

in his abdominal distention and for at least twenty-four hours the liver dullness had been obliterated. He was fairly tender over the entire abdomen. There was increased resistance of all the abdominal muscles, but more markedly so in the epigastrium. There was no muscle spasm. Although the absence of liver dullness indicated a perforation, there had been no change in his temperature or pulse, no change in the leucocyte count, which had been made at frequent intervals, no nausea or vomiting, and no sudden change in his general condition. For several days he had been steadily becoming worse, but the frequent hemorrhages and the long continued fever could easily explain this gradual change. There had been nothing comparable to the typical abdominal pain, the increase in the pulse rate, the drop in temperature and the increased leucocyte count, seen in intestinal perforations. Free fluid could not be made out in the peritoneal cavity.

An operation was agreed upon. While the diagnosis of intestinal perforation was regarded as most probable because of the absence of liver dullness and the progressive distention, a minority still protested this conclusion. On the way to the operating room Doctor Baetjer was consulted about the X-ray which had been taken only a few hours before. Fortunately the röntgenogram, which had been suggested for a pulmonary possibility, included the upper part of the abdomen. At once the diagnosis was unmistakable. The liver was widely separated from the diaphragm by a collection of gas. The difference in density between the body tissues and the gas had produced a remarkable contrast which precisely defined the contiguous structures. The lines of the domes of the diaphragm were almost as clear as in a photograph of an anatomical preparation. The liver was just as sharply outlined. Where the liver is attached to the diaphragm, the X-ray showed a fusion of these structures (Fig. 1).

The operation disclosed free gas in the abdominal cavity and a general peritonitis. A large almost gangrenous ulcer near the centre of the transverse colon had several pin-point perforations. A finger-like strand of omentum had wandered over and become adherent to this area and effectively sealed the base of the ulcer with its multiple perforations. The size of the ulcer precluded excision; a colostomy was made at the site of the ulcer. The patient died the following day. The entire colon was honeycombed with typhoid ulcers. The absence of acute symptoms of intestinal perforation was readily explained by the fact that the perforations were small and were quickly closed by the protecting band of omentum.

Since these instructive X-ray findings, we have awaited other cases of intestinal perforation to further test the practical value of a röntgenographic diagnosis, but such a case has not appeared at a time convenient to obtain a röntgenogram.

The gas which escapes from the alimentary canal need not necessarily

be in the region of the diaphragm. This will doubtless depend upon two factors: (1) the position of the body, and (2) the amount of gas. Air or gas in the peritoneal cavity will rise to the diaphragm if the daphragm is higher than the pelvis; and conversely, will pass to the pelvis if the pelvis is higher than the diaphragm. If the abdominal cavity is well filled with air, all intra-abdominal spaces will contain air. No doubt cases of intestinal perforation will be observed in which adhesions will localize the infection and the escaping gas to a restricted area of the peritoneal cavity. It is, therefore, necessary to include in the röntgenogram any area of the peritoneal cavity suspected because of signs or symptoms. The patient must be placed in the proper position so that the gas may be better localized to the desired part of the abdomen rather than be scattered diffusely throughout the abdominal cavity.

It is obvious that because of the mobility of the gas in the peritoneal cavity it will only be possible to determine that a perforation exists and not to localize the perforation to any particular part of the digestive tract. Röntgenography of free gas in the abdomen should be of the greatest value in perforations which develop insidiously or in cases of trauma in which there are multiple lesions or in which the signs and symptoms of perforation are masked by other causes. Though most gastric and duodenal perforations give a frank unmistakable history of a perforation, many give subjective and objective manifestations which render a differential diagnosis difficult. Typhoid perforations are notoriously difficult to recognize in the brief interval following a perforation in which an operation may be successful. Perforations of carcinomata and of chronic ulcers of the alimentary canal are frequently preceded by a period of reaction, in which the surface of the lesion becomes adherent to the abdominal wall or other contiguous structures. Colon gas will then become localized in the abscess which results from the perforaton. Such a localized collection of gas we have found in the röntgenogram from a case of chronic ulcer of the sigmoid flexure. The abscess and collection of gas was in the buttock. A sinus tract led to the affected area of bowel. In a case of extensive amœbic ulceration of the descending colon, an abscess of the abdominal wall had resulted from perforation of the bowel. In this case a collection of gas was detected by percussion and later demonstrated in the radiogram. Gas contained in such abscesses is presumptive evidence of the presence of the colon bacillus and therefore of a lesion which has had its origin from the intestinal tract.

INDUCED PNEUMOPERITONEUM

Shadows produced in the röntgenogram represent differences in density. There are three general levels of density in the body: (1) Air and gases; (2) soft tissues and fluids; and (3) bone and calcified tissues. The third, or bone density level, may be artificially produced by filling spaces with

suspensions or solutions, such as collargol, thorium, bismuth, etc., having a density far greater than the surrounding tissues. The first, or air density level, can be artificially produced by replacing or adding to the contents of cavities with air or any one of various other gases. This use of air has proved invaluable in pneumoventriculography and later in röntgenography of the subarachnoid spaces. We now propose to inject air into the peritoneal cavity and obtain shadows of the various intra-abdominal organs.

Theoretically, hydrogen should be superior to air and should be the gas with the highest possible radiographic properties, because its molecular weight is lowest. It will be interesting to study the relative radiographic values of various gases, but we know from a practical standpoint that many cases throw a shadow in the röntgenogram. The shadow of gas from the colon bacillus has been mentioned. Infections of Bacillus Welchii (gas bacillus) were accurately diagnosed during the war by the X-ray shadows of the gas which was produced by this organism. The shadow of carbon dioxide gas (CO_2) is shown in one of the accompanying figures (Fig. 4). This gas is conveniently produced in the stomach by the well known mixture of tartaric acid and sodium bicarbonate. Oxygen has occasionally been injected into joints in order to produce sharper definition of the bone margins. The air which is normally present in the body has been most useful in röntgenography, although its importance has been but little recognized. The heart is conspicuous in a röntgenogram because it is surrounded by the air in the lungs. The paranasal and other sinuses in the skull are demonstrable because of the air which is contained in them. We should doubt whether any gas will meet all conditions so satisfactorily as does air. It is sterile, and consequently needs no special preparation and no handling. All other gases must be prepared with more or less difficulty, and sterilization of the containing vessels in addition to the gases will be necessary to insure safety from infections.

We have injected air into the peritoneal cavities of several dogs, and the organs are as strikingly defined [2] as the diaphragm and liver shown in the case of intestinal perforation (Fig. 1). The position of the subject is all-important in obtaining an X-ray of the desired structure. Since the air rises, the liver, spleen, and diaphragm are best outlined by elevating the head of the animal; the pelvic organs, by elevating the pelvis. The results obtained are most remarkable; undoubtedly, the more air surrounding the organ, the sharper will be its definition. The accompanying figures are self-explanatory. It will be seen that very thin structures, such as the diaphragm of a dog, stand out very sharply. Even more remarkable is the sharp definition in many places of the walls of the

[2] The accompanying röntgenograms of induced pneumoperitoneum were taken by Miss Mary Stuart Smith.

intestines. The walls of the intestines can be defined only when the air is present both in the interior and on the exterior of the bowel. In the accompanying photographs (Figs. 2 and 3) the air in the interior of the bowel is that which is normally present. It is possible by stomach tube, or better, by tartaric acid and sodium bicarbonate taken by mouth, to fill the stomach (Fig. 4) and upper intestine with gas, or by rectal injection to fill the colon with air, and to obtain a view of the interior of these organs. This we have done several times in human cases (Fig. 4), none of which, however, had pathological lesions which should have been demonstrable. We have not yet combined the intra-alimentary and intraperitoneal injections of air. Such a combination of injections should outline tumors in the alimentary tract as well as the size and contour of the intestines.

In the dog we injected 500 c.c. of air into the peritoneal cavity. X-rays of this animal's abdomen clearly outlined the diaphragm, the liver, the spleen, both kidneys, the duodenum, a loop of small intestine, the bladder, the descending colon and sigmoid flexure, and cross-sections of loops of intestines.

The intraperitoneal air injections have had no apparent effect upon the animal's well-being. The air slowly absorbs, doubtless directly into the blood. No attempt has been made to determine the exact length of time required for the air to completely disappear, although an X-ray taken four days after a large injection showed a considerable amount (probably about one-third) still present.

We have as yet made no intraperitoneal injections of air in patients, although we feel that the procedure is safe and should offer much valuable information which may lead to correct diagnoses in obscure cases. By determining the exact shape, size and position of various abdominal structures, a big lead will be obtained not only as to the exact organ which is diseased but also as to the pathology of the organ involved. Many patients may thereby be spared a useless exploratory laparotomy by the disclosure of inoperable conditions, whereas others may be offered specific rather than exploratory operations, or a rational rather than an empirical form of treatment.

CONCLUSIONS

1. Perforation of the intestines or the stomach can be diagnosed by the X-ray findings—pneumoperitoneum.

2. The escaping intestinal gases accumulate under the diaphragm if the head is elevated. The röntgenogram shows the diaphragm and liver sharply outlined and a collection of air separating these structures.

3. Localized collections of gas in the abdominal walls, the buttocks, etc., may betray a colon infection and therefore an abscess resulting from a perforated bowel.

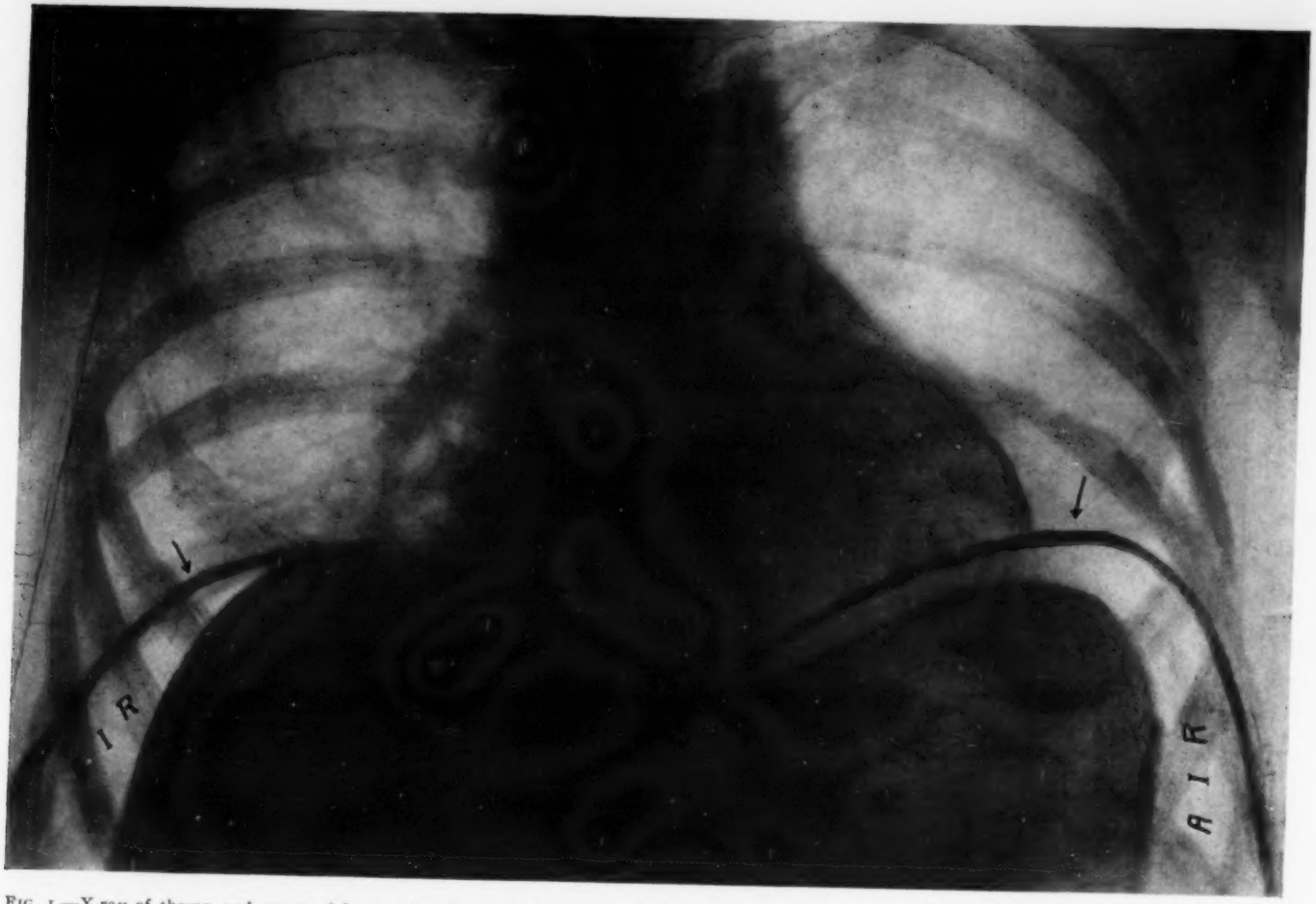

FIG. 1.—X ray of thorax and upper abdomen of patient with intestinal perforation. Note the accumulation of air—pneumoperitoneum—under both domes of the diaphragm. The diaphragm is very sharply defined, except at the "uncovered area" of the liver where the attachment is not separable. The margins of the liver are even more distinct.

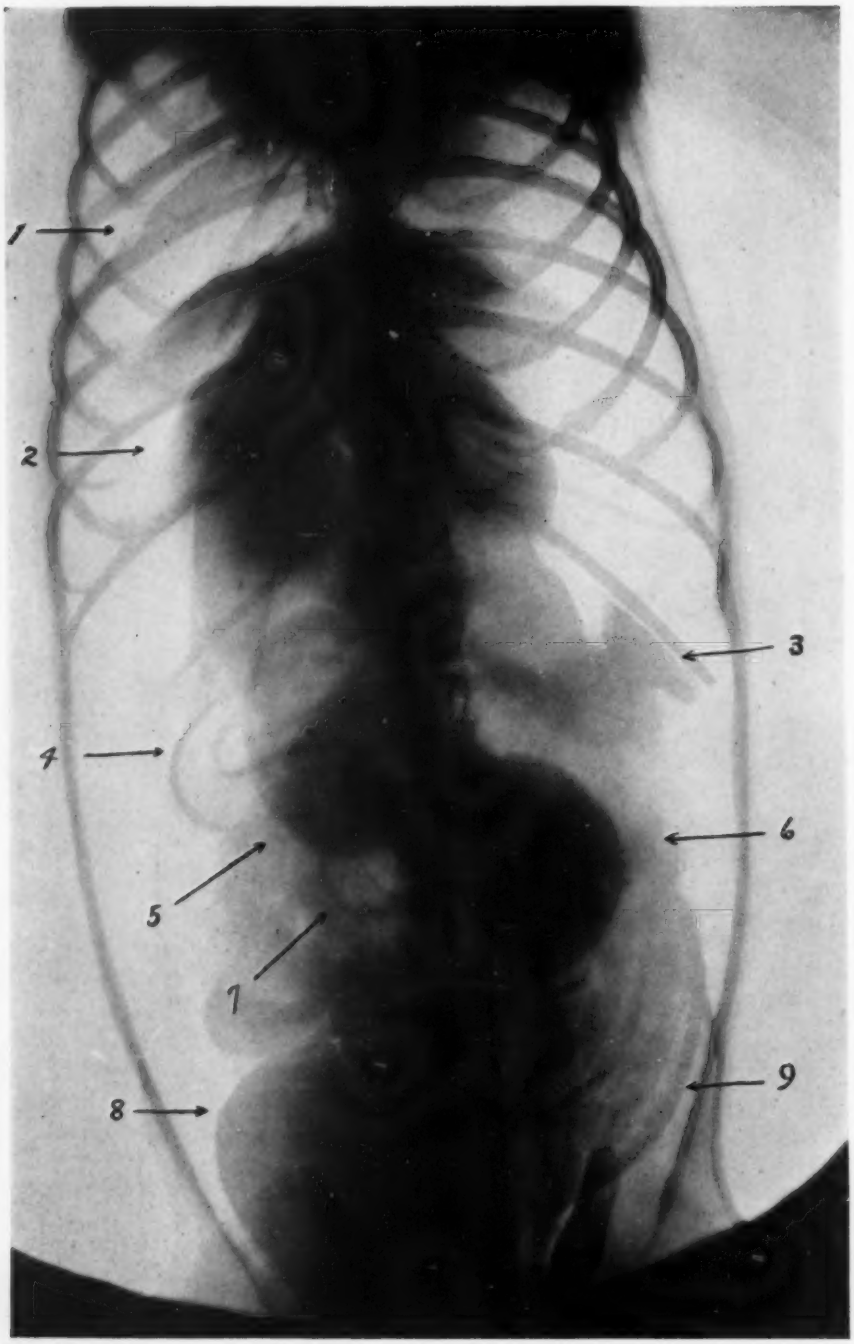

FIG. 2.—X-ray of the abdomen of a dog with artificially induced pneumoperitoneum. The animal is lying in the ventral position. The injection of air (500 c.c.) is adequate to demonstrate practically all the intra-abdominal organs. 1, diaphragm; 2, liver; 3, spleen; 4, duodenum (note the sharp definition of the walls of the bowel); 5, right kidney; 6, left kidney; 7, cross-section of the lumen of small intestine; 8, bladder; 9, descending colon and sigmoid flexure.

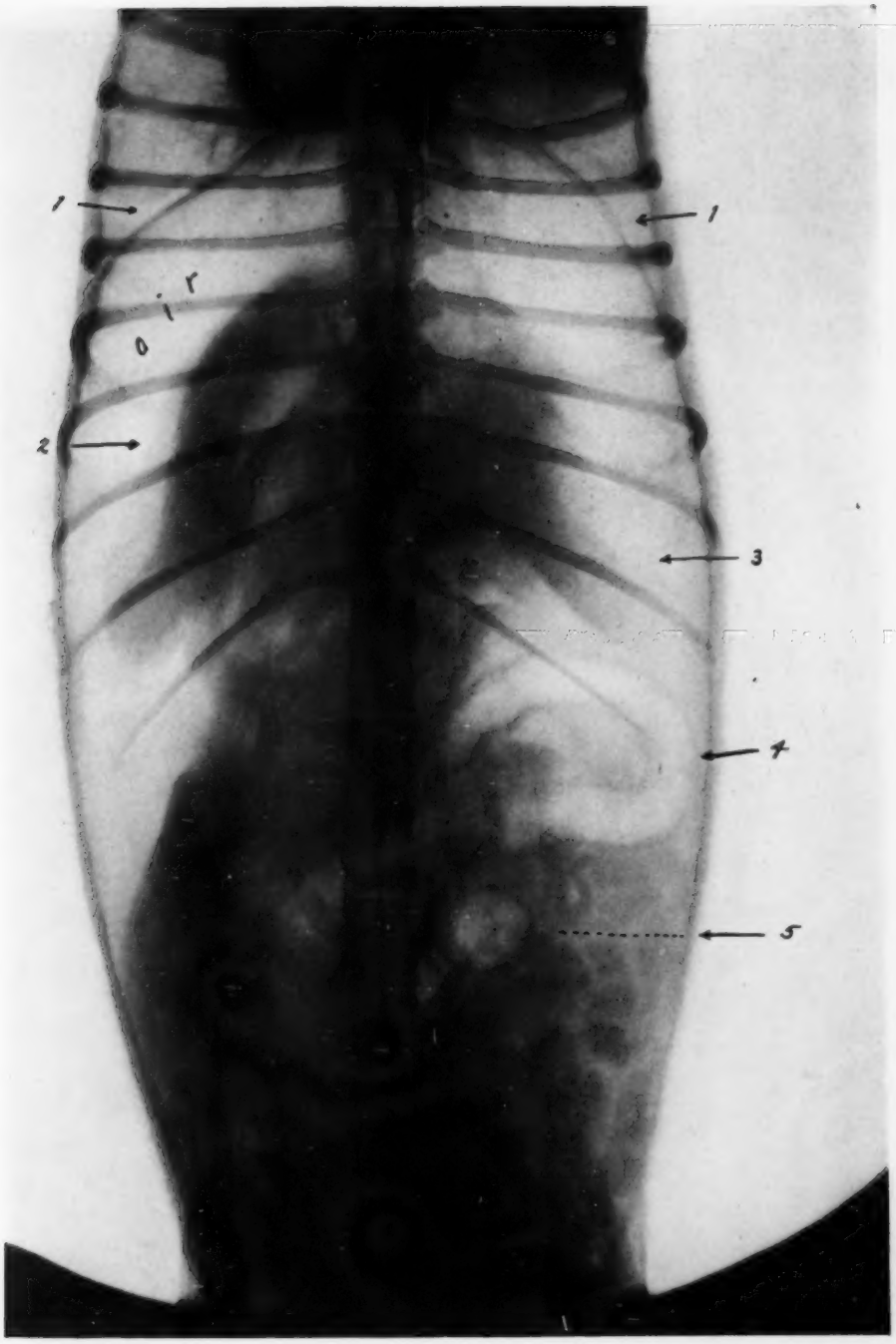

FIG. 3.—X-ray of same dog as in Fig. 2, four days later. Roughly, about two-thirds of the air has been absorbed. The animal's head is elevated, causing the air to collect in the upper abdomen. The animal is in the dorsal position; for this reason the kidney outlines are not seen as in Fig. 2. 1, diaphragm; 2, liver; 3, spleen; 4, loop of small intestine. The sharp outlines of the intestinal walls are explained by the presence of gas internally and air externally. 5, cross-section of the lumen of a loop of small intestine.

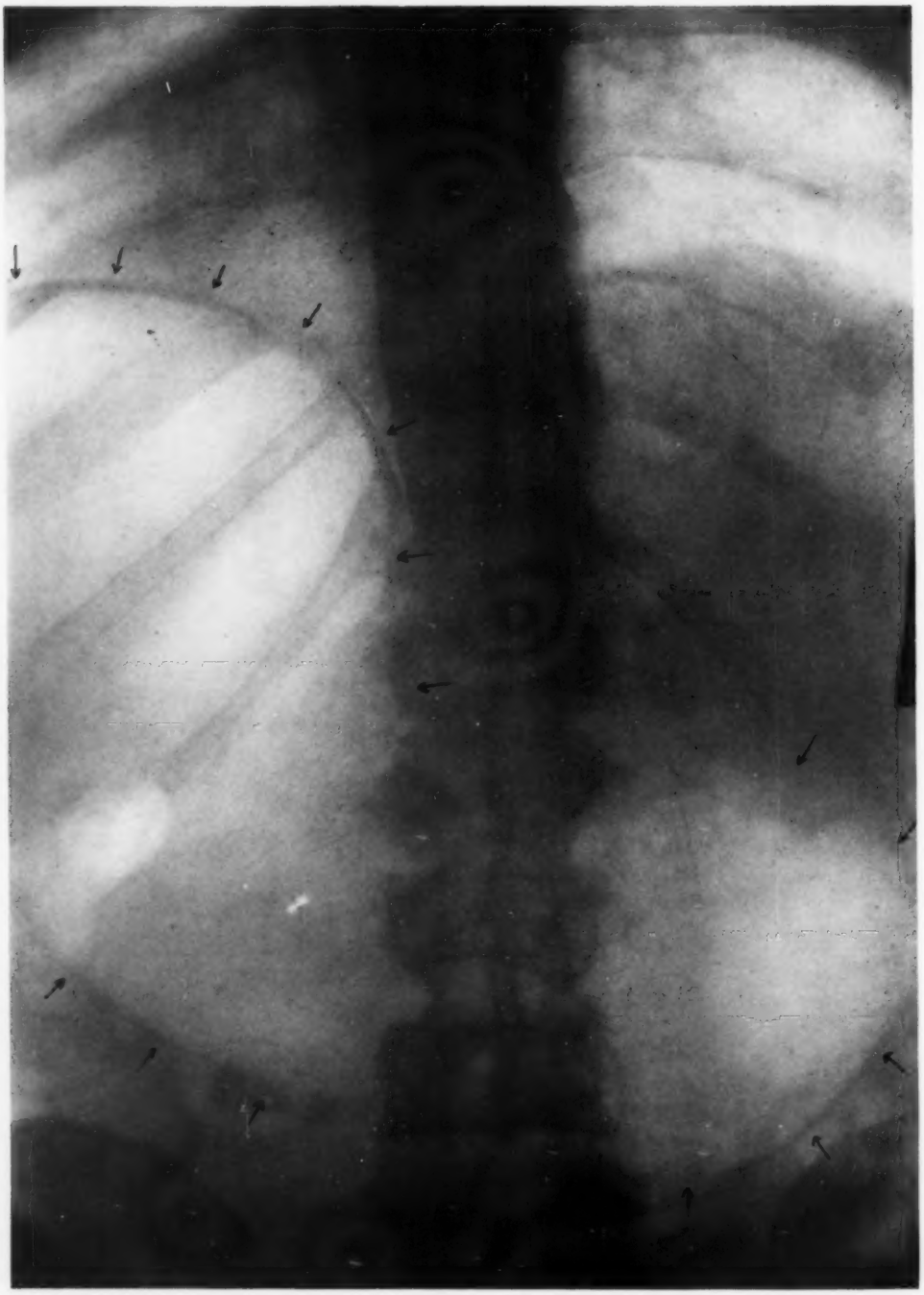

FIG. 4.—Stomach blown up by tartaric acid and sodium bicarbonate taken by mouth. The patient subsequently had an exploratory laparotomy, but no gastric lesion was present. The arrows indicate the outlines of the stomach; the upper border represents the diaphragm and wall of the stomach.

4. An artificial pneumoperitoneum can be produced by injecting air into the peritoneal cavity.

5. In the production of pneumoperitoneum, air is superior to other gases because it can be so readily obtained and because its sterilization is not necessary.

6. Nearly all the abdominal organs can be sharply defined in the röntgenogram after the introduction of air into the peritoneum. Even the intestinal walls are sharply defined.

7. By determining the size, shape, and position of the abdominal organs, induced pneumoperitoneum should prove to be of great value in the localization and diagnosis of intra-abdominal lesions.

CORRESPONDENCE

CHRONIC INFLAMMATORY TUMOR OF OMENTUM

A review of the recent literature for articles on primary tumors of the great omentum indicates that these lesions are exceedingly rare. This fact, following a personal experience with such a tumor, has stimulated my interest in the subject. The patient was a man aged thirty years, recently discharged from the National Army as physically fit. At twelve years of age had an attack of indigestion with right-sided pain; three similar sub-acute attacks in last two years; never in bed, but has missed work for few days. Has had several attacks of diarrhœa in last year. Habitually avoids cabbage, bread, fats and pork. No other acute illness or infection. Well and working up to May 4, 1919. That night had a severe attack of right-sided pain; vomited only after cathartic; was unable to sleep. Seen at office May 6, 1919. Temperature, 99.4°; pulse, 90. General examination negative, tenderness and rigidity along lower right rectus. Evening temperature at hospital, 100. Leucocytes, 12,000; urine, negative; complains of pain and fullness in abdomen.

Operation (May 7).—Right rectus incision, free bloody fluid in peritoneum. Presenting in wound is a soft friable, apparently necrotic mass which tears easily and bleeds. The edges of the mass were made out to extend well into the pelvis, above nearly to the transverse colon, laterally from the outer edge of the right rectus to the outer edge of the left rectus muscle, and there was a definite line of demarcation between the mass and the normal omentum. The mass was removed with a margin of normal omentum on all sides, between ligatures and the opening in the omentum closed with catgut. A small adherent and somewhat inflamed appendix was also removed. The convalescence was a-febrile and uneventful. Two months after the operation, the last report, patient was working and in good condition. Sections of the mass showed fatty degeneration and dense round-cell infiltration to a degree suggesting a mixed cell sarcoma. There was no considerable hæmatoma or hemorrhagic infiltration, and no torsion of the omentum.

I am collecting data for a more extensive report on the subject and shall greatly appreciate receiving case reports or suggestions from readers of the ANNALS OF SURGERY.

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